2017-1395

In The
United States Court of Appeals
For The Federal Circuit

ATLAS IP, LLC,

Plaintiff- Appellant,

v.

ST. JUDE MEDICAL, INC., ST. JUDE MEDICAL S.C., INC., PACESETTER, INC., and BIOTRONIK, INC.

Defendants - Appellees.

APPEAL FROM THE UNITED STATES PATENT AND TRADEMARK OFFICE, IPR2014-00916

APPELLANT ATLAS IP, LLC'S OPENING BRIEF

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CERTIFICATE OF INTEREST

Counsel for Appellant Atlas IP, LLC certifies the following:

1. The full name of every party or amicus represented by me is:

   Atlas IP, LLC

2. The name of the real party in interest (if the party named in the caption is not the real party in interest) represented by me is:

   N/A

3. All parent corporations and any publicly held companies that own 10 percent of the stock of the party or amicus curiae represented by me are:

   None.

4. The names of all law firms and the partners or associates that appeared for the party or amicus now represented by me in the trial court or agency or are expected to appear in this court are:

   Matthew Topic from Loevy & Loevy represents Atlas for the appeal. George C. Summerfield, Rolf O. Stadheim, Kyle L. Harvey, Robert Spalding, and Christopher St. Peter from Stadheim & Grear and Matthew Pasulka from Atlas IP represented Atlas in the trial court.

Dated: April 28, 2017

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TABLE OF AUTHORITIES

ABBREVIATIONS

The '734 Patent	U.S. Patent No. 5,371,734
Atlas	Patent Owner-Appellant Atlas IP, LLC
St. Jude	Collectively Petitioners-Appellants St. Jude Medical, Inc., St. Jude Medical S.C., Inc. and Pacesetter, Inc.
Biotronik	Petitioner-Appellant Biotronik, Inc.
Natarajan	Collectively U.S. Patent No. 5,241,542 and Natarajan, *et. al.*, *Medium Access Control Protocol for Wireless LANs (An Update)*, IEEE P802.11/92-39 (1992)[1]
Board	Patent Trial and Appeal Board

[1] As the Board noted, the two references are "substantially similar," and the Board also referred to the two references collectively as "Natarajan" and "the Natarajan References." Appx35, n.7

STATEMENT OF RELATED CASES

The following cases are related to this appeal, as they pertain to infringement of the ‘734 Patent at issue:

Atlas IP, LLC v. Medtronic, Inc., App. Nos. 2015-1071, 2015-1105 (Fed. Cir.);

Atlas IP, LLC v. St. Jude Med., Inc., App. No. 2015-1190 (Fed. Cir.);

Atlas IP, *LLC v. Medtronic*, *Inc.*, No. 13-civ-23309 (S.D. Fla.);

Atlas IP, LLC v. Medtronic, Inc., No. 14-civ-22065 (S.D. Fla.);

Atlas IP, LLC v. St. Jude Med., Inc., No. 14-civ-21006 (S.D. Fla.);

Atlas IP, *LLC v. Boston Scientific Corp*. No. 14-civ-02856 (D. Minn.);

Atlas IP, LLC v. Biotronik, Inc., No. 14-civ-20602 (S.D. Fla.);

Atlas IP, LLC v. City of Naperville, No. 15-C-10744 (N.D. Ill.);

Atlas IP, *LLC v. Pac. Gas & Elec. Co.*, No. 15-C-05469 (N.D. Cal.);

Atlas IP, LLC v. Florida Power &Light Co., No. 16-cv-21679 (S.D. Fla.);

Atlas IP, *LLC v. CenterPoint Energy Energy Houston Electric, LLC*, No. 16-cv-00396 (E.D. Tex.);

Atlas IP, LLC v. Oncor Electron Delivery Co., LLC, No. 16-cv-00397 (E.D. Tex.);

Atlas IP, *LLC v. DTE Electric Co.*, No. 15-cv-14265 (E.D. Mich.);

Atlas IP, *LLC v. Texas-New Mexico Power Company*, No. 16-cv-01396 (E.D. Tex.);

Atlas IP, *LLC v. Telematics Wireless USA, Corp. and Telematics Wireless, Ltd.*, No. 16-cv-01231 (E.D. Tex.);

Atlas IP, LLC v. Master Meter, Inc., No. 16-cv-01214 (E.D. Tex.);

Atlas IP, LLC v. Denton County Electric Cooperative, Inc., d/b/a CoServe Electric, No. 16-cv-01395 (E.D. Tex.);

Atlas IP, LLC v. Mueller Systems, LLC, No. 16-cv-01213 (E.D. Tex.);

Atlas IP, LLC v. Ekahau, Inc. and AiRISTA, LLC, No. 16-cv-01213 (E.D. Tex.); and

Atlas IP, LLC v. Denton Municipal Electric, No. 16-cv-01397 (E.D. Tex.)

JURISDICTIONAL STATEMENT

This Court has jurisdiction over this appeal pursuant to 28 U.S.C. § 1295(a)(4)(A).

STATEMENT OF THE ISSUE

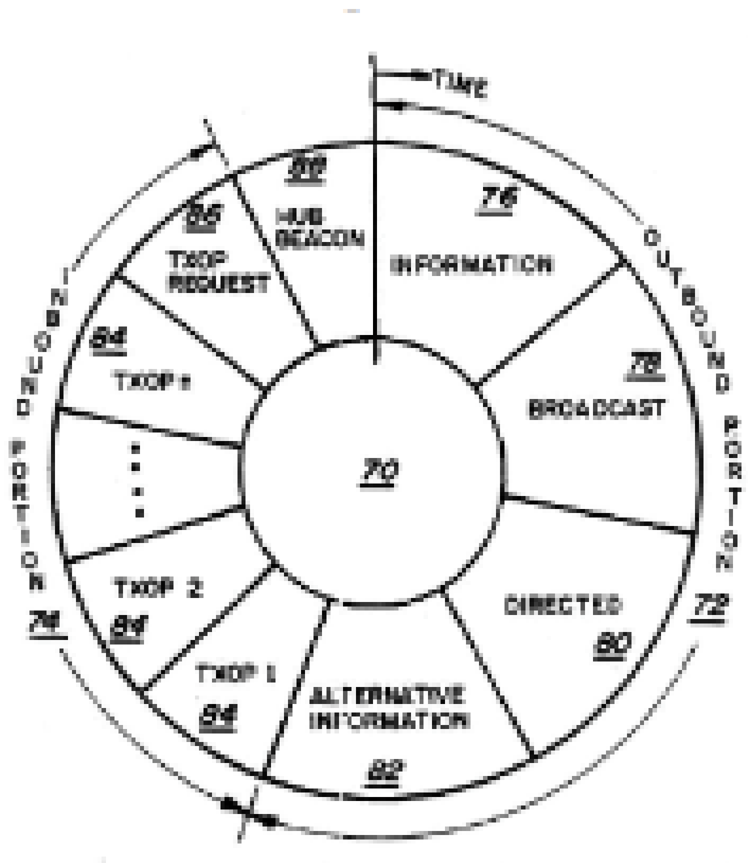
Whether the Board erred in finding claims 6, 11, 14, and 21 of the '734 Patent are unpatentable in light of, *inter alia*, Natarajan.

STATEMENT OF THE CASE

A. The '734 Patent

The '734 Patent relates to a medium access control ("MAC") protocol for use in wireless network communications. Appx3 and Appx8. The Summary of the Invention section of the '734 Patent explains that the disclosed protocol "avoids many of the disadvantages associated with the inefficiencies of" prior art protocols, such as "high overhead requirements," and "collisions and saturations." Appx61, col. 5, lines 14-25. Such protocol also "obtains significant reductions in battery power drain by permitting the receivers as well as the transmitters of the communicator stations to be powered off during a majority of the time, but selectively and predictably powered on to send or receive relevant communications." *Id.*, col. 5, lines 28-33.

For communication among a group of communicators, one communicator is designated as a "hub" and the remaining communicators are designated as "remotes." Appx4. Figure 3 of the '734 Patent illustrates a communication cycle in accordance with the MAC protocol:



Id.

Figure 3 illustrates communication cycle 70, which is established by the hub to control outbound transmissions from the hub to the remotes and to control inbound transmissions from the remotes to the hub. *Id*. Outbound portion 72 begins with information interval 76, during which the hub transmits control and other information to the remotes. *Id.* at Appx 4-5. This information indicates the predetermined times when each remote will be able to participate in the communication cycle. Appx5. Broadcast interval 78 allows the hub to broadcast the same information to all of the remotes. *Id.* Directed packet interval 80 allows

the hub to transmit frames to specifically identified remotes. *Id.* Outbound portion 82 concludes with alternative information interval 82, during which the hub repeats the information provided in information interval 76. *Id.*

Of particular importance to this appeal, the remotes can determine in advance when they should expect to receive frames transmitted from the hub and when they may transmit frames to the hub based on information about the intervals in a communication cycle received from the hub. Appx6. As a consequence, remotes can power down their receivers and transmitters at other times to conserve battery power. *Id.* This transmitted information also reduces overhead, and instructs the remotes when to participate in communications so as to avoid collisions in transmissions.

Representative claim 14 of the '734 Patent, with the "transmitting" limitation highlighted, reads as follows:

> A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:
>
> designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;
>
> the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

> **the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub**;
>
> the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;
>
> the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;
>
> the hub establishing the length of each communication cycle; and
>
> the hub transmitting a frame containing information describing the length of the communication cycle prior to the end of the communication cycle whose length is established.

Appx83, col. 49, lines 31-68 (emphasis added).

B. The IPR Proceedings And Shifting Claim Construction

St. Jude filed an IPR petition for claims 6, 11, 14, 21, and 44 of the ’734 Patent. Appx2. The Board instituted a review of claims 6, 11, 14, and 21. *Id.* After institution, Biotronik filed an IPR petition and moved for joinder with the St. Jude proceeding. *Id.* The Board instituted IPR of the ‘734 Patent and joined the two proceedings. *Id*. Atlas responded to the petition and St. Jude filed a reply. *Id.* An oral hearing was held on July 15, 2015. *Id.*

On December 3, 2015, the Board issued its final written decision finding that: (i) claims 6, 14, and 21 of the ’734 Patent are anticipated by Natarajan, (ii)

claim 11 is unpatentable for obviousness over the combination of Natarajan and Bella; (iii) claims 6, 14, and 21 are unpatentable for obviousness over the combination of Natarajan and Bantz; and (iv) claim 11 is unpatentable for obviousness over the combination of Natarajan, Bantz, and Bella.

Atlas requested rehearing of the final written decision to address the Board's interpretation of the phrase "the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle" (the "transmitting" limitation). Appx35-36. The "transmitting" limitation was construed by this Court, after the oral hearing in the St. Jude IPR proceeding, as requiring "that the starting time and duration of the cycle and of remote-transmission intervals within each cycle must be communicated by the hub to the remotes before the time at which the remotes may begin transmitting." *Atlas IP, LLC v. St. Jude Med., Inc.*, 804 F.3d 1185, 1187-88 (Fed. Cir. 2015). This Court also stated in *Medtronic* that "[a]ll of this makes clear that the hub must set up a schedule of intervals and send that schedule to the remotes before the transmission-opportunity slots for the remotes arrive." *Atlas IP, LLC v. Medtronic, Inc.*, 809 F.3d 599, 606 (Fed. Cir. 2015). The Board granted Atlas's request for rehearing, but affirmed its determination that the "transmitting" limitation "only requires the hub to transmit starting time and duration of the communication cycle and at least two intervals." Appx33-34, Appx39, Appx42.

In its petition, St. Jude originally told the Board that the "transmitting" limitation in the challenged claims should be construed to mean "the hub transmitting to the remotes information necessary to know ***in advance*** the starting time and duration for the communication cycle and the plurality of predesignated intervals during each communication cycle." Appx112 (emphasis added). St. Jude failed to specify in advance of ***what*** in its proposed construction. The Board, in its decision to institute, determined that this was one of the limitations that did not require express construction at that stage of the proceedings. *See* Appx161-166; Appx11.

In the co-pending St. Jude district court litigation, the district court originally construed the "transmitting" limitation to mean "the hub transmitting to the remotes information necessary to know in advance the starting time and duration of the communication cycle and of each of two or more predeterminable intervals during each communication cycle." *Atlas IP, LLC v. St. Jude Med., Inc.*, 804 F.3d 1185, 1187-88 (Fed. Cir. 2015). On summary judgment, however, St. Jude successfully urged that the district court narrow the term "in advance" in the foregoing construction to mean that "the information specifying 'when the communication cycle starts and its duration . . . must be transmitted in advance of the very communication cycle at issue.'" *Id*. at 1188. This Court vacated the district court's construction, and held that the "transmitting" limitation required

"that the starting time and duration of the cycle and of remote-transmission intervals within each cycle must be communicated by the hub to the remotes ***before the time at which the remotes may begin transmitting***," answering the "in advance" question left unanswered by St. Jude's construction, and eschewing the notion that such information need only be for "two or more" of the subject intervals. *Id.* (emphasis added).

This Court entered its claim construction ruling in the co-pending *St. Jude* matter after oral argument in the *inter partes* review, but before the Board's final decision, and the Board authorized the parties to file limited supplemental briefing on the impact of this Court's ruling. Appx2-3. In that supplemental briefing, St. Jude acknowledged that this Court's claim construction required that, to be anticipatory, a prior art reference must teach the hub's transmission at the start of a communication cycle "the length of ***all intervals*** in the cycle," as opposed to merely "two or more" of such intervals. Appx186. (emphasis in original).

The Board, in its final decision finding the challenged claims unpatentable, stated that this Court's "construction of the 'transmitting' limitation is consistent with that proffered by [St. Jude] in this proceeding in that both constructions require the hub to transmit the start time and duration of the communication cycle ***and its constituent intervals*** in advance." Appx12 (emphasis added). The Board also recognized that, pursuant to this Court's construction, the subject information

must be transmitted from the hub to the remotes "before the transmission opportunities for the remotes begin." *Id.*

In opposing Atlas's petition for rehearing, St. Jude notably changed its view of claim construction, arguing for the first time that the information transmitted by the hub to the remotes pursuant to this Court's construction need only establish the communication cycle and "two or more" predeterminable intervals, *i.e.*, the information sent by the hub to the remotes need not establish all of a communication cycle's constituent intervals. Appx196. The reasons for this change becomes apparent when one considers Natarjan's teachings, as discussed in the next section.

The Board, also changing its position on claim construction, adopted St. Jude's belatedly modified construction, holding that "the 'transmission' limitation only requires the hub to transmit the starting time and duration of the communication cycle ***and at least two intervals***." Appx38 (emphasis added). Using this claim construction, the Board, while determining to rehear the matter below, declined to disturb its ruling regarding the unpatentability of the challenged claims. Appx42.[2]

In sum, then, the "transmitting" limitation of the challenged claims has gone from a term needing no construction, to a term meaning that the hub transmits "the

[2] Neither St. Jude nor the Board relied upon the other references below–Bantz and Bella–as teaching the claimed "transmitting" limitation.

start time and duration of the communication cycle and its constituent intervals" "before the transmission opportunities for the remotes begin," to a term meaning that the hub transmits "the starting time and duration of the communication cycle and at least two intervals the hub to transmit the starting time and duration of the communication cycle." As explained herein, none of these constructions are correct because they do not reconcile with this Court's construction of that limitation, *i.e.*, "the starting time and duration of the cycle and of remote-transmission intervals within each cycle must be communicated by the hub to the remotes before the time at which the remotes may begin transmitting."

C. Natarajan

1. Background

Natarajan 1992 describes a MAC protocol for wireless local area networks. Appx13. The network architecture includes a finite number of Access Points through which mobile stations communicate. *Id*. Inbound and outbound communication between an Access Point [hub] and mobile stations [remotes] is structured as a sequence of "frames." *Id.* A frame contains three time intervals—Periods A, B, and C. Appx14. Immediately before each of Periods A, B, and C, the Access Point broadcasts control information to the mobile stations in a header, shown as AH, BH, and CH in Figure 1. Appx14. As St. Jude's expert Dr. Zygmund Haas opined that each of Natarajan's Periods A-C is further comprised

of "time slots," which are themselves the "intervals" during which Natarajan's Access Point and mobile stations actually transmit and receive frames to and from one another. Appx252 at ¶ 117. *See also* Appx121 ("the slots in Period B (also 'intervals')").

Natarajan's frame structure is depicted in Natarajan's Figure 1:

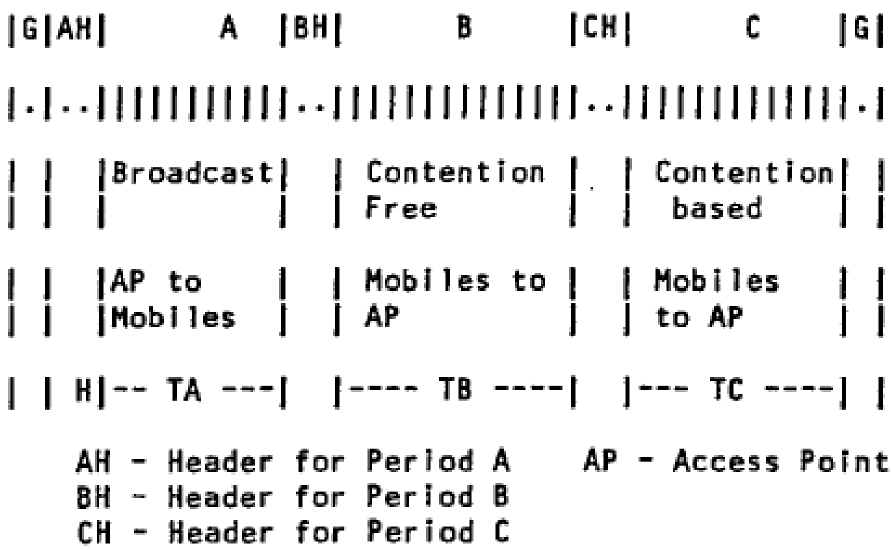
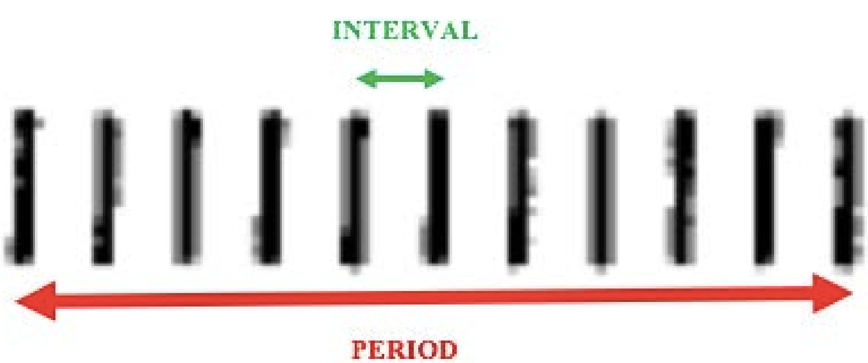


Figure 1. Frame Structure of Medium Access Control Scheme

Appx320, Fig. 1.

The following figure highlights a Natarajan "Period," along with the constituent time slot intervals:



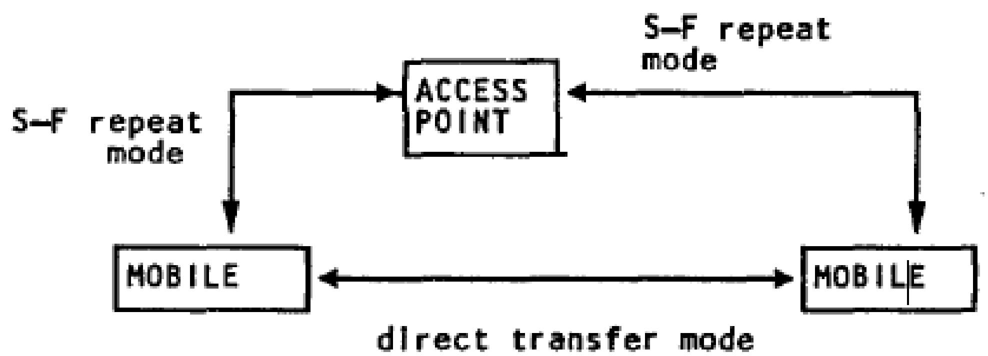
While Natarajan's Period B is comprised of slotted intervals allocated to particular mobile stations (Appx322), Period C is contention-based, where the mobile stations "contend for the channel and transmit a message without any explicit allocation from the Access Point" (Appx323). Prior to Period C, the Access Point transmits Header CH, which contains the length of Period C ("TC"), thereby allowing the mobile stations to set their timers to know when to expect the header for the next Frame. Appx326.

Using the Slotted-ALOHA of Natarajan's Period C:

> [E]ach mobile station that has a message to transmit will do so only at the beginning of a time slot. At the end of each transmission, the users must know if their packets were received correctly (i.e., without collisions) or not. If a collision is detected (by lack of a positive ACK), the mobile station schedules a retransmission of the collided packet according to a retransmission scheduling algorithm.

Id.

Also, during Period C (and other periods), "[a] mobile station may (or may not) be able to communicate directly to another mobile station registered with the same Access Point. In the Store-and-Forward repeat mode, a mobile station communicates through the Access Point to another mobile station in the network." Appx327. This is shown in Natarajan's Figure 7:



Id.

In light of the foregoing, during Period C, the Natarajan remotes have their transmitters on at times other than intervals in which they are allowed to transmit to the hub, *i.e.*, when they are merely contending for bandwidth for such transmission, and when they are transmitting to other remotes.

2. St. Jude's Discussion Of Natarajan

In its petition, St. Jude equated the claimed "communication cycle" to the "frame" disclosed in the Natarajan references. Appx114. St. Jude further describes each Natarajan Frame as having "multiple intervals, including periods A, B, and C." Appx119. And, according to St. Jude, "[e]ach of the Periods A, B and C are predesignated time periods established by the hub." Appx120.

St. Jude also equated the claimed "hub" and "remotes" to Natarajan's Access Point and mobile stations, respectively, as shown in the diagram below:

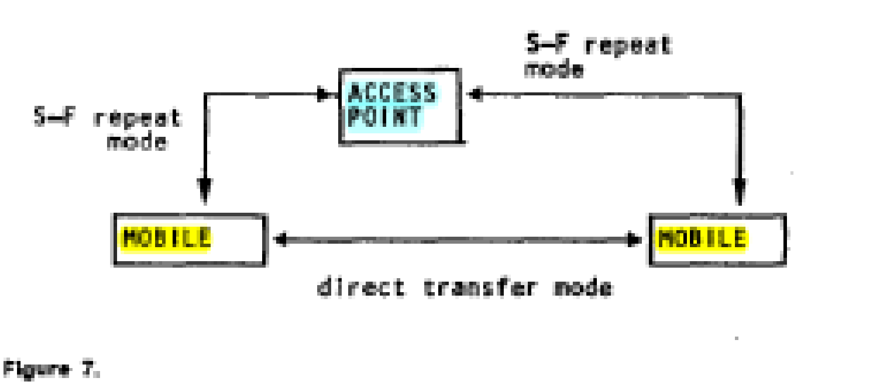


Figure 7.

See Appx115 (Figure 7 "shows two 'mobile units (highlighted yellow) and an 'access point' (blue) in communication").

St. Jude originally represented to the Board that Natarajan satisfies the "transmitting" limitation of the subject claims because "information transmitted during headers AH, BH and CH . . . establish the communication cycle and a plurality of predeterminable intervals during each communication cycle." Appx121. St. Jude further stated that in Natarajan, "the hub transmits the necessary information ***in headers AH, BH and CH*** for the remotes to know in advance the start time and duration of each interval, and of the frame (communication cycle) as a whole." Appx122 (emphasis added). According to St. Jude's own view of Natarajan, then, some of the communication cycle information (*i.e.*, that communicated in Headers AH and BH), is transmitted to the remotes before the remotes are allowed to transmit to the hub (*i.e.*, before Period B), and some of that information is transmitted after the remotes are allowed to transmit to the hub (that communicated in Header CH). As the applicant for the '734 Patent

argued during prosecution, Natarajan "apparently requires the receivers of the mobile units to power up at least three times during the communication cycle simply to receive the header control information . . . As a result of this 'scheduled' protocol, there would appear to be more power consumed than if the complete information concerning all the intervals and functions during each complete cycle is communicated at one time." Appx408.

St. Jude's expert, Dr. Haas, opined that "[t]he periods A, B, and C are predesignated time periods established by the hub . . . because the hub transmits control information within the headers AH, BH, and CH, which establish the intervals A, B, and C." Appx253 at ¶ 119. *See also* Appx255 at ¶ 123 (Natarajan "discloses that AH, BH, and CH to [*sic*] establish the communication cycle and a plurality of predeterminable intervals during each communication cycle"). Dr. Haas further opined that - "[i]nformation ***that remains relevant*** at the transmission of BH and CH is transmitted in those intervals." Appx254 at ¶ 121 (emphasis added). "The remotes use information sent ***in headers AH, BH and CH*** to determine when it is possible to turn their transmitters and receivers off." Appx258 at ¶ 131.

St. Jude also originally cited Figure 2 from Natarajan 1992 (reproduced below) for the proposition that "the length of each interval and header is provided in header AH:"

- TA = Length of Period A
- TB = Length of Period B
- TC = Length of Period C
- TAH = Length of Header AH
- TBH = Length of Header BH
- TCH = Length of Header CH
- TREMHOP = Remaining Length of Hop
- BSID = Unique Id of the Access Point
- NET_ID = Network Id
- Next Frequency to be used in the Slow Frequency Hopping pattern
- List of Receiving Stations
- Broadcast Data Indicator Flag

Figure 2. Control Information in Header AH

Appx120-121.

However, according to St. Jude, only "***[s]imilar*** information on future intervals is re-broadcast in header BH and CH." Appx121 (emphasis added). In fact, St. Jude made clear that different information is transmitted in the different headers, as, for example, Header BH contains unique information about the "slot allocation for each remote, such that each remote can determine exactly when to turn on its transmitter." Appx121.

Dr. Haas opined that Natarajan "discloses that transmission opportunities for the remotes are assigned by the hub at predesignated times and communicated to the remotes in header BH." Appx259 at ¶ 134. *See also* Appx260 at ¶ 135 ("The Txop information is transmitted as a list of mobile stations and allocated slots in header BH"). And, to be clear, Dr. Haas considers the time slots comprising

Natarajan's Periods A through C to be themselves "intervals," as depicted in Natarajan's Figure 1.[3] Appx252 at ¶ 117.

Similarly, Header CH contains the length of Period C, and, uniquely, the "[c]urrent estimate of users actively attempting transmission in Random Access Section." Appx240 at ¶ 91. Dr. Haas quoted Natarajan's characterization of Header C as a "***special*** message" broadcast to all mobile stations, "identifying the end of the Period B and the beginning of the Period C." *Id.* at ¶ 90 (emphasis added).

Natarajan's Header CH is followed by "contention" Period C, where the mobile stations attempt transmission to the Access Point. Appx241 at ¶ 92. The contention-based nature of Period C creates a significantly increased possibility of collision. *Id.* If there is a collision, then the remotes involved will attempt re-transmission after waiting for a requisite "random period of time." *Id.* The waiting periods will be different for different remotes to reduce the likelihood of additional collisions. *Id.*

[3] In its opposition to Atlas's rehearing request, St. Jude introduced for the first time the notion of vagueness as what constitutes an "interval" in Natarajan. *See* Appx197 ("This potential vagueness in the term 'interval' is evident from Atlas's own rehearing request"). Of course, as noted herein, when it filed its petition, St. Jude (along with its expert) was perfectly clear as to what constitutes an "interval" in Natarajan–the Periods comprising a Frame and the time slots comprising a Period.

At the very least, according to St. Jude's own characterization of Natarajan, information about Period C time slot intervals in which the mobile stations are allowed to send and re-send data to the Access Point is not transmitted to the mobile stations until after Period B, *i.e.*, ***after*** the mobile stations are allowed to transmit to the Access Point in Period B. Further, there is no clear indication of information about a frame and its constituent periods sent in Natarajan's Header AH remains immutable in Headers BH and CH. Certainly, St. Jude did not urge such immutability until the impact of this Court's construction became clear. And, as discussed above, St. Jude's evidence presented to the Board tends to support the conclusion that the information sent in Headers AH, BH, and CH about Periods A-C is indeed different.

3. The Board's Treatment Of Natarajan

The Board's discussion of Natarajan also changed over the course of time in light of this Court's construction of the "transmitting" limitation. In its institution and final decisions, the Board discussed Natarajan's frame structure, which substantially tracks St. Jude's initial characterization of Natarajan, and the following is a summary of that discussion.

The Board, agreeing with St. Jude, found that Natarajan's "Frame" is "similar" to the claimed "communication cycle." *See* Appx13. In Natarajan's first interval of a frame (Period A), outbound traffic is transmitted from the Access

Point to mobile stations. Appx167; Appx13. In the second interval (Period B), bandwidth is allocated for contention-free inbound data transmitted from mobile stations to the Access Point. *Id.* The third interval (Period C) is used for contention-based transmission. *Id.* During this interval, mobile stations can, *inter alia*, submit requests for bandwidth in subsequent frames. *Id*.[4]

Immediately before each of Periods A, B, and C, the Access Point broadcasts control information to the mobile stations in Headers AH, BH, and CH. Appx167; Appx14. Header AH also includes a list of mobile stations that will receive data packets from the Access Point during Period A. Appx167; Appx15. On correct reception of Header AH, each mobile station can determine whether it will receive packets from the Access Point during Period A. Appx15. A mobile station that does not expect to receive data during Period A can power down its receiver at the beginning of Period A, and set a timer to power on the receiver at the end of Period A, in time to receive Header BH. Appx15.

Header BH identifies the beginning of Period B. Appx15. The control information in Header BH includes a list of ordered pairs indicating the mobile stations that are allowed to transmit data packets to the Access Point (or other remotes) during Period B, and the number of time slots in Period B allocated to

[4] Although not expressly discussed by the Board in either decision, Natarajan's Period C is also used for the transmission of data packets by the mobile stations–it is not reserved solely for bandwidth requests and is minimally 20% of the frame to accommodate bursty transmissions but can enlarge to 100%. Appx328.

each mobile station. Appx167-168; Appx15. Based on the information in Header BH, a mobile station can determine whether it has been allocated slots during Period B and will power on its transmitter and transmit packets according to the ordered slot allocation information. Appx167-168; Appx15.

The Board's institution and final decisions do not contain a specific description of Natarajan's Header CH. In its decision on rehearing, the Board again did not actually provide a description of what it believed to be contained in Natarajan's Header CH. The Board did acknowledge Atlas's characterization of the information contained in that header as "unique." Appx37. Nonetheless, the Board took issue with the proposition that Natarajan's remotes "do not have the requisite information about the communication cycle until they receive Header CH." *See* Appx39. According to the Board, "[e]ven if the length of Period C can change from one communication cycle to another, the length of Period C (i.e., TC) for a particular communication cycle is transmitted initially as part of Header AH and then ***repeated*** in Headers BH and CH." *Id.* (emphasis added), *citing* Appx321-323, Appx 326.

The portions of Natarajan cited by the Board do not actually say that any header information is "repeated." Appx321-323, Appx 326. Natarajan does teach that Headers AH, BH and CH all contain TC, which represents the length of Period C. However, nothing in Natarajan says that TC is immutable in between the times

the Access Point transmits Headers AH and CH. Further, and logically, if the lengths of Natarajan's Periods do not change during a Frame, and TC remains constant, then there would be no reason for Header CH to convey the end Period B, and the beginning and length of Period C. *See*, *e.g.*, Appx326 (Header CH identifies "the end of Period B and the beginning of Period C" and transmits TC, the "length of Period C").

Further, the Board did not address the lack of ***any*** transmitted information from the Access Point to the mobile stations about the time slot intervals in Natarajan's Period C until ***after*** the mobile stations have had the opportunity to transmit to the access point in Period B. Further, as explained above, as Natarajan's Period C is contention-based, the mobile stations decide when to transmit during that Period C. In contrast, as this Court noted, the '734 Patent teaches that "***the hub*** must set up a schedule of intervals and send that schedule to the remotes before the transmission-opportunity slots for the remotes arrive." *Atlas IP, LLC v. Medtronic, Inc.*, 809 F.3d 599, 606 (Fed. Cir. 2015) (emphasis added).

The Board, in its rehearing decision, suggested that it had earlier excluded that period from "the plurality of predeterminable intervals established by the 'transmitting' limitation" in Natarajan. Appx41, *citing* Appx17-19. This is demonstrably incorrect. The Board, in its final decision, began by equating

Natarajan's "Frame" to the claimed "communication cycle." Appx13. The Board then noted that Natarajan's Frame "contains three time intervals—Periods A, B, and C." Appx14. In further describing Natarajan's Frame, the Board described how Natarajan's Headers AH through CH contain the lengths of Periods A through C. *Id.* There would have been no reason for the Board to have included this description had Period C truly been excluded from the predeterminable intervals of Natarajan's Frame.

The Board also characterized St. Jude's petition as originally excluding Period C from the "predetermined intervals" of Natarajan's Frame. As noted above, however, St. Jude in its petition very clearly identified Periods A, B ***and*** C as the "predesignated time periods established by the hub." Appx120. At no point in the petition, or at any other time prior to rehearing, did St. Jude ever urge that Period C should be excluded from Natarajan's Frame for purposes of determining whether Natarajan anticipates the subject claims. In fact, not even in its opposition to rehearing did St. Jude argue that Period C should be excluded from a Frame.

D. Claim 11

Claim 11 uniquely contains a limitation requiring the hub to "revok[e] a previous transmission opportunity allocation of a remote which has not transmitted more than a predetermined number of frames during a previous number of

communication cycles." Appx22. The board found that the combination of Natarajan and Bella teaches these limitations because:

> Like Bella, Natarajan 1992 describes a system in which mobile stations make reservation requests for slot allocation. If a mobile station requests isochronous service, the requested number of slots will be allocated to the mobile station in Period B of every frame until ***the mobile station cancels the allocation by sending a cancellation request***. Thus, Natarajan 1992 teaches 'revoking a previous transmission opportunity allocation of a remote,' as recited in claim 11, when the hub receives a cancellation request from the remote. If the system of Natarajan 1992 instead utilized Bella's ***cancellation method***, which revokes a previous transmission allocation when a remote transmits no packets in a communication cycle, we are persuaded by Petitioner's argument that the combination would result in 'the hub revoking a previous transmission opportunity allocation of a remote which has not transmitted more than a predetermined number of frames' (zero) 'during a previous number of communication cycles' (one). Furthermore, if Natarajan 1992 employed the cancellation technique of Bella, the hub would be 'monitoring the frames transmitted by each remote during its transmission opportunity.'

Appx23-24 (emphasis added).

The Board, in making this finding, equates a remote ***cancelling*** a transmission opportunity with a hub ***revoking*** such an opportunity. This the Board had to do, as Bella "allows the implementation of packet-switched synchronous speech communications in the network without requiring ***any centralized device*** synchronizing all the network stations." Appx341 (emphasis added). As St. Jude's expert notes, in Bella, "[w]hen the communicator wishes to stop transmitting data, it will simply stop." Appx269 at ¶ 155. According to Dr. Haas, "[w]hen the communicator holding the reservation stops sending packets during the reserved

timeslot, each communicator notices this, and cancels the reservation." *Id.* The actual teaching from Bella cited by Dr. Haas reads "[t]he lack of packets transmitted onto the line is automatically interpreted by the other stations, without any specific information, as the clearing of the connection and the corresponding time slot ***is made available for asynchronous data traffic***." Appx357, col. 11, lines 9-13 (emphasis added). This is not a teaching of cancellation.

In contrast, the '734 Patent teaches that, "if the Txop 84 is not used by the remote 66 for a predefined number of communication cycles 74, the hub 64 may determine that it is not necessary to preserve a Txop for a particular remote 66, and thereafter cancel the Txop 84 allotted to that remote 66." Appx64, col. 12, lines 41-46. In other words, "cancellation" is not simply a matter of a remote ceasing to transmit. Further, the subject claim language requires that one communicator (hub) monitor the transmissions and cancel the transmission opportunity of another communicator (remote). Appx82, col. 48, lines 31-36. This is distinct from a communicator simply discontinuing transmission, as taught in Bella.[5]

[5] The Board also found claim 11 obvious in light of the combination of Natarajan, Bella, and Bantz. Appx28. However, the Board did not rely upon Bantz for an independent teaching of the "revoking" limitation of that claim. *See id.*

E. Claim 21

Claim 21 uniquely contains a limitation requiring the hub to "transmit two frames containing information to establish the plurality of predeterminable intervals during each communication cycle, the second frame containing the information to established (sic) the plurality of predeterminable intervals occurring before the intervals in which the remotes are allowed to transmit frames to the hub." Appx21. The Board found that the combination of Natarajan and Bantz teaches these limitations because Header AH is a first frame containing timing information for Periods A, B, and C, and for Headers AH, BH, and CH. Appx321-322; *see* Appx264 at ¶ 146. Header BH is a second frame containing timing information for the allocated slots in Period B. St. Jude does not dispute that claim 21 requires two frames transmitting information about either establishing the cycle or about all the intervals in a communication cycle, not just some of them. Appx372. The very portion of Natarajan cited by St. Jude demonstrates that this does not happen.

SUMMARY OF ARGUMENT

This Court made clear in *St. Jude* that the "transmitting" limitation, a limitation of each claim at issue below, required "that the starting time and duration of the cycle and of remote-transmission intervals within each cycle must be communicated by the hub to the remotes before the time at which the remotes

may begin transmitting." *St. Jude*, 804 F.3d at 1188. Before the import of this construction became apparent, St. Jude was clear that Natarajan contains different types of "intervals," as that term is used in the subject claims–the Periods comprising a Frame (which corresponds to a claimed "communication cycle") and, the time slots comprising a Period. St. Jude also characterized Natarajan's Frame establishing information as being transmitted during Headers AH through CH, and that the information contained in those headers differs from header to header. St. Jude succeeding in preliminarily convincing the Board that this reading of Natarajan was correct.

It was only after St. Jude recognized the import of this Court's claim construction ruling, *i.e.*, that all of the subject cycle-establishing information needs to be transmitted to the remotes before the remotes are allowed to transmit to the hub, that St. Jude changed its view of Natarajan. Thereafter, all of the information required to establish a Natarajan Frame became purportedly contained in Header AH. Further, Period C no longer counted as an interval in Natarajan's Frame, and even what corresponded to an "interval" in Natarajan became vague. Finally, this Court's construction requires that information be transmitted about "two or more" (as opposed to all) intervals of a claimed communication cycle.

With regard to this Court's construction, neither St. Jude nor the Board is entitled to change, modify, add to, subtract from, or simply ignore that

construction. This Court made clear that information about ***all*** intervals in a claimed communication cycle must be transmitted to the remotes–not just "two or more" such intervals, as St. Jude belatedly argues. And, when this Court's construction is used, as opposed to St. Jude's revised construction, it is clear that Natarajan does not teach transmitting to the remotes the requisite information about all constituent intervals of a putative communication cycle before the remotes are allowed to transmit to the hub. Additionally, Natarjan does not teach that the mobile stations (remotes) power off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub. Under the circumstances, the Board's determination that the subject claims are unpatentable in light of Natarajan's teaching was erroneous.

ARGUMENT

A. Standard Of Review

The Board's decisions on issues of claim construction are reviewed *de novo*¸ except to the extent they involve underlying factual issues, which are reviewed for substantial evidence. *In re Cuozzo Speed Techs., LLC*, 778 F.3d 1271, 1282-83 (Fed. Cir. 2015). The Board's ultimate determination of anticipation and obviousness are legal questions reviewed *de novo,* but underlying factual findings are reviewed for substantial evidence. *In re Baxter Int'l, Inc.*, 678 F.3d 1357, 1361

(Fed. Cir. 2012). Substantial evidence is "such relevant evidence as a reasonable mind might accept as adequate to support a conclusion." *In re Gartside*, 203 F.3d 1305, 1312 (Fed. Cir. 2000) (citation omitted).

B. The Proper Construction Of The "Transmitting" Limitation

1. This Court's Previous Claim Construction Ruling

As discussed above, this Court has clearly and unambiguously construed the "transmitting" limitation of the challenged claims as requiring "that the starting time and duration of the cycle and of remote-transmission intervals within each cycle must be communicated by the hub to the remotes before the time at which the remotes may begin transmitting." *St. Jude*, 804 F.3d at 1188. In rendering this construction, this Court examined in detail the teachings of the '734 Patent, which it was required to do. *Phillips v. AWH Corp*., 415 F.3d 1303, 1316 (Fed. Cir. 2005 (*en banc*)).

Particularly, in the related *Medtronic* appeal, the Court highlighted the following teachings:

> If the hub does not define the intervals when the hub will transmit to the remotes and when each remote will transmit to the hub, multiple communicators (e.g., the hub and remote or two remotes) could transmit simultaneously and their signals would collide
>
> * * *
>
> To fulfill the core claimed function of power savings, each remote must know when its receiver and transmitter can be off and must be on, which naturally, perhaps necessarily, calls for the scheduling information to arrive

> before any remote transmissions begin.
>
> * * *
>
> And the claim confirms the centrality of the timing of the information transmittal when it adds a further limitation requiring that the crucial information be transmitted twice before remote transmissions begin: the hub 'transmitting two frames containing information to establish the plurality of predeterminable intervals during each communication cycle, the second frame containing the information to establish[] the plurality of predeterminable intervals occurring before the intervals in which the remotes are allowed to transmit to the hub.' All of this makes clear that the hub must set up a schedule of intervals and send that schedule to the remotes before the transmission-opportunity slots for the remotes arrive.

Atlas IP, LLC v. Medtronic, Inc., 809 F.3d 599, 605-06 (Fed. Cir. 2015).

St. Jude's response to this discussion below was to admonish the Board not to accept this "collage of quotations as a reason to require that the hub transmit 'complete information' about all possible intervals in a communication cycle." Appx197. This "collage of quotations," as St. Jude puts it, is this Court's discussion of the evidence intrinsic to the '734 Patent. As noted in *Phillips*, this is ***precisely*** the information that should be considered in determining claim scope.

2. The Deviation From This Court's Previous Construction

Once the alleged "collage of quotations" was removed from consideration, according to St. Jude, the Board was free to consider a communication cycle and only at least two of such cycle's constituent intervals, where such intervals include an interval: (a) when the hub is allowed to transmit frames to the remotes; (b) when the remotes are allowed to transmit to the hub; and (c) when each remote is

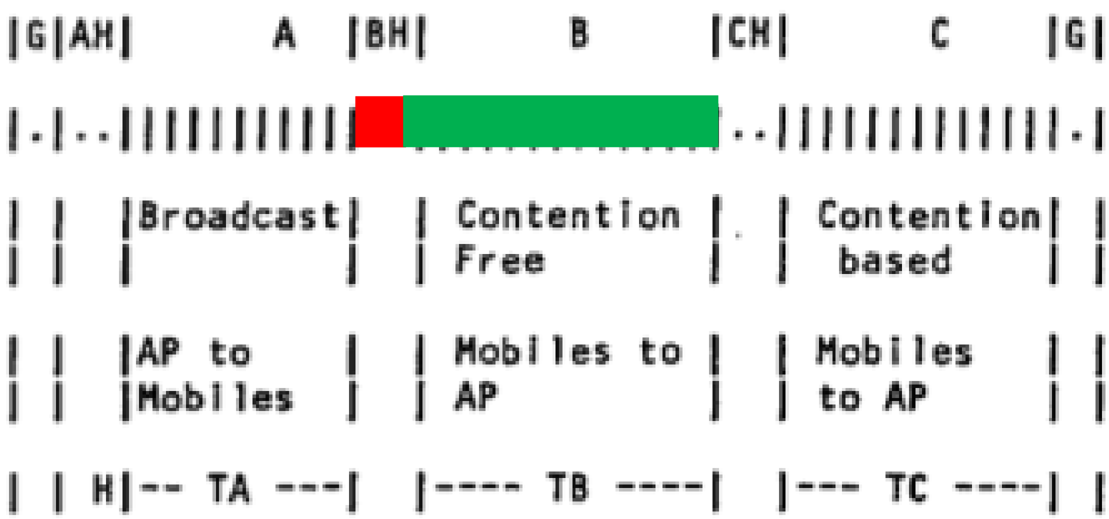
expected to receive a frame from the hub.[6] Appx198. To be clear, however, only when one ignores the Court's afore-referenced discussion of the '734 Patent does it become possible to consider "at least two" (as opposed to all) intervals of a communication cycle. By way of example, the following illustrates the result when one only considers information about "at least two" (as opposed to all) of Natarajan's time slot intervals:

The Natarajan time slot interval highlighted in red correspond to interval types (a) and (c), referenced above (hub allowed to transmit frames to remotes and each remote expected to receive a frame from the hub). The time slot interval highlighted in green represents interval type (b) (remotes are allowed to transmit to the hub). This leaves 20 other time slot intervals that are excluded from consideration under St. Jude's view of claim construction. The two highlighted intervals in the foregoing example, then, are those for which the hub transmits "the starting time and duration" to the remotes pursuant to this Court's construction. Presumably, under that construction, no such information need be transmitted for the remaining 20 intervals. In other words, the remotes are unable to determine

[6] Intervals A and C are not "mutually exclusive." Appx195.

whether they are allowed to transmit during those 20 intervals, and, relatedly, whether they must have their transmitters on, or whether their transmitters may be powered down during such intervals.

A similar result attains when one considers Natarajan's Periods and Headers, which St. Jude also characterizes collectively as "intervals" (Appx198).



Again, the "interval" highlighted in red (Header BH) corresponds to interval types (a) and (c). The "interval" highlighted in green (Period B) corresponds to interval type (b). These are the intervals, under St. Jude's view, for which the hub must transmit the requisite information to the remotes. This leaves Headers AH and BH and Periods A and C for which no such information need be transmitted, meaning that, for those "intervals," the remotes are left to other means to determine whether they are allowed to transmit and/or should be expected to receive data.

The foregoing examples, which avail themselves of St. Jude's "two or more" view of claim construction, clearly do not comport with the goals of the '734 Patent invention – efficient bandwidth usage and power conservation.[7] In fact, only by the hub's transmission of "the starting time and duration of the cycle and of remote-transmission intervals within each cycle," as this Court has stated, can these goals be accomplished. St. Jude apparently agreed with this proposition, as it acknowledged that, to be anticipatory, a prior art reference must teach the hub's transmission at the start of a communication cycle "the length of ***all intervals*** in the cycle," as opposed to merely "at least two" of such intervals. Appx186 (emphasis in original).

Further, as explained above, Natarajan's Period C is entirely contention-based, meaning that the mobile stations (remotes) determine on their own when to attempt transmission to the Access Point (hub). This is contrasted with the Federal Circuit's clear characterization of the '734 Patent's invention as requiring that ***the hub*** "set up a schedule of intervals." *Medtronic*, 809 F.3d at 606. Thus, independently, Natarajan fails to teach the invention claimed in the '734 Patent.

Apart from its inconsistency with the aims of the '734 Patent, St. Jude's "at least two" notion of claim construction is found nowhere in this Court's previous

[7] That Natarajan may not teach these examples expressly is of no moment. They are used simply to illustrate the error of the "at least two" construction urged by St. Jude, which was the claim construction ultimately used by the Board in finding the claims unpatentable.

construction. Although "at least two intervals" was part of the district court's construction reviewed in the *St. Jude* appeal, that construction was vacated. *St. Jude*, 804 F.3d at 1190.

The Board, in its final decision finding the challenged claims unpatentable, stated that this Court's "construction of the 'transmitting' limitation is consistent with that proffered by [St. Jude] in this proceeding in that both constructions require the hub to transmit the start time and duration of the communication cycle ***and its constituent intervals*** in advance." Appx12 (emphasis added). There was no mention of "at least two" intervals. Ultimately, however, the Board committed error in agreeing with St. Jude that the "at least two" claim construction was correct, despite there being no such concept in this Court's earlier construction. *See* Appx38.

3. The Applicability Of This Court's Prior Claim Construction Ruling

There can be little doubt that this Court's previous construction of the "transmitting" limitation controls in this Appeal. In the first place, the doctrine of collateral estoppel precludes St. Jude from rearguing claim construction. That doctrine applies if: "(i) the issue previously adjudicated is identical with that now presented, (ii) that issue was 'actually litigated' in the prior case, (iii) the previous determination of that issue was necessary to the end-decision then made, and (iv) the party precluded was fully represented in the prior action." *See, e.g., Thomas v.*

Gen. Servs. Admin., 794 F.2d 661, 664 (Fed. Cir. 1986).[8]

The issues are indeed identical, *i.e.*, the proper construction of the "transmitting" limitation pursuant to a district court analysis, given the expiration of the '734 Patent in January 2013. *See In re Rambus*, 694 F.3d 42, 46 (Fed. Cir. 2012). The meaning of the "transmitting" limitation was clearly litigated, as is evident from a review of this Court's decision in *St. Jude*. *See St. Jude*, 804 F.3d at 1188. Also evident from that decision is the central nature of the Court's construction to the infringement issue. *See id.* at 1191 ("We conclude that the district court erred in construing the 'transmitting' limitation to require that the starting time and duration of a communication cycle be sent in advance of the communication cycle. Because there is no ruling about infringement under any other claim construction, we vacate the summary judgment of non-infringement and remand for further proceedings"). Finally, St. Jude was fully represented by its counsel, Gibson, Dunn & Crutcher LLP. *Id.* at 1185.

Under the circumstances, collateral estoppel clearly works to bar re-litigation of claim construction in this matter. So does the doctrine of waiver, which provides that a party waives a claim construction argument for appeal purposes that is not presented below. *See Sage Prods., Inc. v. Devon Indus., Inc.*,

[8] Ordinarily, this Court would look to the law of the regional circuit for the elements of collateral estoppel. *See, e.g., Tegal Corp. v. Tokyo Electron Co.*, 2002 U.S. App. LEXIS 1992 at *16-17 (Fed. Cir. 2002). However, as this is an appeal from the Board, there is no regional circuit law to consider.

126 F.3d 1420, 1426, (Fed. Cir. 1997) (applying waiver by precluding Sage's claim construction differing from the claim construction urged at trial); *Key Pharms. v. Hercon Labs. Corp.*, 161 F.3d 709, 715 (Fed. Cir. 1998) (condemning proffer of a new claim construction that differed from the claim construction urged at trial); *N. Telecom Ltd. v. Samsung Elecs. Co.*, 215 F.3d 1281, 1290 (Fed. Cir. 2000) (noting with "extreme disfavor" a claim construction that differed from the claim construction Samsung advanced at trial). Here, not only did St. Jude fail to argue below the inapplicability of this Court's earlier claim construction, it actually urged the Board to follow this Court's "actual construction." Appx197-198. St. Jude has waived the right to argue otherwise on appeal.

Finally, as this Court made clear in *Phillips*, a central goal in any claim construction exercise is predictability. *Phillips v. AWH Corp.*, 415 F.3d 1303, 1323 (Fed. Cir. 2005 (*en banc*). Obviously, this goal is best fulfilled when the same term in the same patent is construed in the same fashion in different proceedings.

C. Natarajan Does Not Teach The "Transmitting" Limitiation

As explained in detail above, Natarajan teaches a Frame consisting of Periods A through C, each such Period being comprised, in turn, of time slots during which the Access Point and mobile stations are allowed to transmit data to one another. St. Jude and its expert both consider these Periods and their

constituent time slots each to be “intervals” within the context of the invention claimed in the ‘734 Patent. Natarajan teaches transmitting nothing about the time slot intervals in Period C during which the mobile stations can attempt to transmit and re-transmit data to the hub (and even to each other) until after Period B has ended. Thus, information about these remote transmission intervals in Period C is transmitted from Natarajan’s Access Point to the mobile stations only ***after*** the remotes have been allowed to transmit in Period B. This means that such information is not transmitted “before the time at which the remotes may begin transmitting,” contrary to this Court’s construction of the “transmitting” limitation.

As a result, Natarajan cannot anticipate or render obvious the challenged claims unless one imports into the construction of the “transmitting” limitation the “two or more intervals” concept proposed by St. Jude, adopted by the Board, omitted from this Court’s previous construction, and contrary to the purposes of the ‘734 Patent. Of course, this should not, indeed ***cannot***, be done, given this Court’s prior claim construction ruling and the reasons therefor.

As for Natarajan’s Headers and Periods, the Board assumes that information about TC, the length of Period C, is the same in each of Headers AH, BH, and CH, even though there is no actual teaching in Natarajan that this is the case. To the contrary, if TC remained constant, once that value has been transmitted in Header AH, there would be no need to re-transmit that same value in Header CH–the

header that uniquely allows the mobile stations to set their timers at the beginning of Period C to know when to expect the header for the next Frame. Appx326. And, as to the evidence presented by St. Jude on this issue, Dr. Haas only ever opined as if the information contained in Headers AH through CH is all used by the mobile stations to govern their transmission and receipt of data:

- "The periods A, B, and C are predesignated time periods established by the hub . . . because the hub transmits control information within the headers AH, BH, and CH, which establish the intervals A, B, and C" (Appx253 at ¶ 119);

- "Information that remains relevant at the transmission of BH and CH is transmitted in those intervals" (Appx254 at ¶ 121); and

- "The remotes use information sent in headers AH, BH and CH to determine when it is possible to turn their transmitters and receivers off" (Appx258 at ¶ 131).

In short, Natarajan does not teach the transmission of the requisite information regarding the start time and duration of all the intervals in a Frame, which means that Natarajan does not satisfy the "transmitting" limitation, as that limitation was construed by this Court.[9]

D. The "Transmitter" Limitation

The claims all require "the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to

[9] The Board also relied upon the Bantz and Bella references in combination with Natarajan for certain obviousness findings. Appx25-28. The Board did not cite these references as teaching the "transmitting" limitation, and therefore cannot be used to solve for the Natarajan's failure to disclose that limitation.

the hub." As noted above, in Natarajan's Period C, the remotes have their transmitters powered on at other times. The Board stated that "a mobile station turns its transmitter off except," *inter alia*, "if the mobile station ***wishes*** to transmit during contention-based Period C." Appx20 (emphasis added). The subject claims, however, are not worded in terms of a remote's "wish." Rather, to anticipate the subject claims, Natarajan must teach that the remotes' transmitters are on only when the remotes are "allowed" to transmit to the hub. Due to the contention-based nature of Natarajan's Period C, no remote is "allowed" to transmit to the hub, yet all remotes potentially have their transmitters powered on. Furthermore, the hub can deny a transmission opportunity to a remote, but if the remote wishes to transmit data, it may do so if the remote desires in period C. In fact, if numerous remotes wish to transmit data because of bursty data transmission needs, they can all contend to transmit, even to each other, without being scheduled by the hub.

E. Claim 11 Is Not Rendered Obvious By The Combination Of Natarajan And Bella

As discussed above, claim 11 contains a limitation requiring the hub to "revok[e] a previous transmission opportunity allocation of a remote which has not transmitted more than a predetermined number of frames during a previous number of communication cycles." Bella teaches a communicator that simply ceases communicating, which is not the revocation of a transmission opportunity. The

Board explains neither how Bella's cessation of transmission equates to transmission opportunity revocation, nor how the combination of Natarajan and Bella renders claim 11 obvious in the absence of a teaching of the "revoking" limitation in that combination and nor that there is a teaching to combine. *See Belden Inc. v. Berk-Tek LLC*, 805 F.3d 1064, 1073 (Fed. Cir. 2015) ("[O]bviousness concerns whether a skilled artisan not only *could have made* but *would have been motivated to make* the combinations or modifications of prior art to arrive at the claimed invention.").

In fact, the PTAB and the Petitioner actually provide an indicia of non-obviousness of claim 21 of the '734 Patent: "[a]ccording to Petitioner, for example, the combination would simplify the cancellation method of Natarajan 1992 by allowing the hub to revoke a time slot allocation when the remote stops transmitting." Appx24. Relying on Dr. Haas's testimony for support, Petitioner also asserts that using Bella's cancellation method makes even more sense when the remotes are mobile, as in Natarajan 1992, because they may move outside of the hub's range abruptly and be unable to cancel their own reservations." *Id*. Without an articulated motivation to combine a non-centrally controlled wired protocol Bella with Natarajan that is only intermittently centrally controlled and wireless, as a matter of law, claim 11 is non-obvious. Similarly there is no motivation to combine three references.

F. Claim 21 Is Not Rendered Obvious By The Combination Of Natarajan And Bantz

As discussed above, claim 21 contains a limitation requiring the hub to "transmit two frames containing information to establish the plurality of predeterminable intervals during each communication cycle, the second frame containing the information to established (sic) the plurality of predeterminable intervals occurring before the intervals in which the remotes are allowed to transmit frames to the hub." And while the information in the frames, according to the Board, not need to be identical, clearly the antecedent basis of "the" plurality of intervals needs to be both overlapping and establish the plurality of intervals. In Header AH, Natarajan establishes the periods, but Header BH only establishes when the remotes are allowed to transmit in Period B, and nothing about the other two intervals–namely when "the hub is allowed to transmit frames to the remotes" (outbound interval) and when "each remote is expected to receive a frame from the hub". Appx83, col. 50, lines 55-62.

In any case, the Board has not shown that each and every element of the Claim 21, namely the "transmitting two frames establishing the plurality of intervals" is not in the prior art in either reference, Claim 21 is not obvious.

CONCLUSION

For the foregoing reasons, the Board's determination that the challenged claims are unpatentable should be vacated, and the matter remanded for further proceedings consistent with such *vacatur*.

RESPECTFULLY SUBMITTED,

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ADDENDUM

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Paper 29
Entered: December 3, 2015

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ST. JUDE MEDICAL, INC., ST. JUDE MEDICAL S.C., INC.,
PACESETTER, INC., and BIOTRONIK, INC.,
Petitioner,

v.

ATLAS IP LLC,
Patent Owner.

Case IPR2014-00916[1]
Patent 5,371,734

Before BARBARA A. BENOIT, LYNNE E. PETTIGREW, and GEORGIANNA W. BRADEN, *Administrative Patent Judges*.

PETTIGREW, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

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[1] Case IPR2015-00534 has been joined with this proceeding.

I. INTRODUCTION

We have jurisdiction to hear this *inter partes* review under 35 U.S.C. § 6(c). This Final Written Decision is issued pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons discussed herein, Petitioner has shown by a preponderance of the evidence that claims 6, 11, 14, and 21 of U.S. Patent No. 5,371,734 are unpatentable.

A. Procedural History

St. Jude Medical, Inc., St. Jude Medical S.C., Inc., and Pacesetter, Inc. (collectively, "St. Jude") filed a Petition for *inter partes* review of claims 6, 11, 14, 21, and 44 of U.S. Patent No. 5,371,734 (Ex. 1001, "the '734 patent"). Paper 2 ("Pet."). Atlas IP LLC ("Patent Owner") filed a Preliminary Response. Paper 6 ("Prelim. Resp."). On December 8, 2014, we instituted an *inter partes* review of claims 6, 11, 14, and 21 of the '734 patent on asserted grounds of unpatentability. Paper 7 ("Dec.").

Subsequent to institution, Biotronik, Inc. ("Biotronik") filed a Petition and a Motion for Joinder with the instant proceeding. *Biotronik, Inc. v. Atlas IP LLC*, Case IPR2015-00534, Papers 1, 2. We instituted an *inter partes* review and granted the Motion, joining Biotronik with St. Jude (collectively, "Petitioner") in this *inter partes* review. Paper 17.

Patent Owner filed a Patent Owner Response to the Petition, Paper 16 ("PO Resp."), and Petitioner filed a Reply to the Patent Owner Response, Paper 18 ("Reply"). An oral hearing was held on July 15, 2015, and a transcript of the hearing was entered into the record. Paper 22.

On October 29, 2015, the United States Court of Appeals for the Federal Circuit issued precedential opinions in appeals from decisions in two district court cases involving the '734 patent. *See Atlas IP, LLC v.*

Medtronic, Inc., No. 2015-1071, 2015 WL 6550622 (Fed. Cir. Oct. 29, 2015) ("*Medtronic*"); *Atlas IP, LLC v. St. Jude Med., Inc.*, 804 F.3d 1185 (Fed. Cir. 2015) ("*St. Jude*"). Pursuant to our authorization, the parties filed supplemental briefing addressing the impact of the *Medtronic* and *St. Jude* Federal Circuit opinions on this proceeding. Papers 24, 25, 27.

B. Related Matters

The parties indicate that the '734 patent has been asserted in several district court actions. Pet. 1; Paper 5, 1. In one of those cases, Patent Owner asserted the '734 patent against St. Jude. *Atlas IP, LLC v. St. Jude Med., Inc.*, No. 1:14-cv-21006 (S.D. Fla.). The Federal Circuit recently vacated the district court's summary judgment of non-infringement in that case and remanded for further proceedings. *St. Jude*, 804 F.3d at 1190. The other recent Federal Circuit decision was an appeal from summary judgment rulings by the district court in *Atlas IP, LLC v. Medtronic, Inc.*, No. 1:13-cv-23309. In that case, the Federal Circuit affirmed the district court's summary judgment of non-infringement, reversed the district court's summary judgment of no anticipation or obviousness, and remanded for further proceedings. *Medtronic*, 2015 WL 6550622, at *10.

C. The '734 Patent

The '734 patent relates to a medium access control ("MAC") protocol for use in wireless network communications. Ex. 1001, 1:16–30. According to the Summary of the Invention, the MAC protocol described in the '734 patent combines beneficial aspects of time division multiple access ("TDMA") techniques, such as predictable transmission opportunities, with aspects of packet reservation multiple access ("PRMA") techniques, such as effective allocation of available bandwidth. *Id.* at 5:14–19. The Summary

of the Invention further states that the disclosed protocol "obtains significant reductions in battery power drain by permitting the receivers as well as the transmitters of the communicator stations to be powered off during a majority of the time, but selectively and predictably powered on to send or receive relevant communications." *Id.* at 5:25–33.

For communication among a group of communicators, one communicator is designated as a "hub" and the remaining communicators are designated as "remotes." *Id.* at 5:42–44. Figure 3 of the '734 patent, reproduced below, illustrates a communication cycle in accordance with the MAC protocol described in the '734 patent:

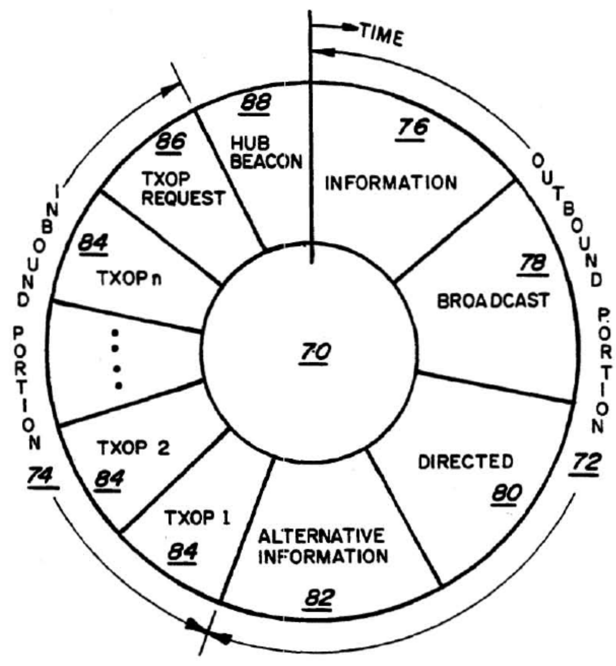

Fig_3

Figure 3 illustrates communication cycle 70 established by the hub to control outbound transmissions from the hub to the remotes and to control inbound transmissions from the remotes to the hub. *Id.* at 7:12–18. Outbound

portion 72 begins with information interval 76, during which the hub transmits control and other information to the remotes. *Id.* at 11:56–59. This information indicates the predetermined times when each remote will be able to participate in the communication cycle. *Id.* at 11:60–62. Broadcast interval 78 allows the hub to broadcast the same information to all of the remotes. *Id.* at 11:62–66. Directed packet interval 80 allows the hub to transmit frames to specifically identified remotes. *Id.* at 11:67–12:1. Outbound portion 82 concludes with alternative information interval 82, during which the hub repeats the information provided in information interval 76. *Id.* at 12:1–9.

During inbound portion 74, those remotes that have requested a transmission opportunity to transmit messages to the hub are provided with an opportunity to do so. *Id.* at 12:14–17. Figure 3 shows transmission opportunities 84, labeled “TXOP 1” to “TXOP n.” *Id.* at Fig. 3. All remotes initially receive a transmission opportunity (or “Txop”) “with (at least) a predefined minimum duration on each communication cycle 70, whether or not they have any frames to transmit.” *Id.* at 12:27–30. The hub may adjust the duration of transmission opportunities based on observed traffic patterns and information received from the remotes regarding the amount of data each remote has queued for transmission. *Id.* at 12:30–34. In addition, if a transmission opportunity is not used by a remote for a predefined number of communication cycles, the hub may cancel the transmission opportunity for that remote in subsequent cycles. *Id.* at 12:41–46. Following transmission opportunities 84 in inbound portion 74, Txop request interval 86 allows remotes that recently have joined the group or have not been allocated a transmission opportunity to transmit messages to the hub to request

allocation of a transmission opportunity in the next communication cycle. *Id.* at 12:47–53.

Based on information about the intervals in a communication cycle received from the hub, the remotes can determine in advance when they should expect to receive frames transmitted from the hub and when they may transmit frames to the hub. *Id.* at 5:47–54, 13:29–33. As a consequence, remotes can power down their receivers and transmitters at other times to conserve battery power. *Id.* at 5:54–66, 13:33–36.

D. Illustrative Claim

Claims 6, 11, 14, and 21 of the ’734 patent are independent and contain many of the same limitations. Claim 6 is illustrative of the claimed subject matter:

> 6. A communicator for wirelessly transmitting frames to and receiving frames from a[t] least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:
>
> designating one of the communicators of the Group as a hub and the remaining the [sic] communicators of the Group as remotes;
>
> the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;
>
> the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames

> to the hub, and when each remote is expected to receive a frame from the hub;
>
> the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;
>
> the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;
>
> the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub;
>
> the hub transmitting transmission opportunity allocation information in a frame transmitted by the hub; and
>
> the hub allocating a number of transmission opportunities during at least one communication cycle which is at least one less in number than the number of remotes in the Group.

Ex. 1001, 46:16–58.

E. Grounds of Unpatentability

We instituted an *inter partes* review of claims 6, 11, 14, and 21 of the ’734 patent on the following grounds of unpatentability:

Reference(s)	**Basis**	**Challenged Claim(s)**
Natarajan 1992[2]	35 U.S.C. § 102(a)	6, 14, and 21
Natarajan 1992 and Bella[3]	35 U.S.C. § 103(a)	11
Natarajan ’542[4] and Bantz[5]	35 U.S.C. § 103(a)	6, 14, and 21
Natarajan ’542, Bantz, and Bella	35 U.S.C. § 103(a)	11

II. DISCUSSION

A. Claim Construction

The ’734 patent expired on January 29, 2013. *See* Pet. 14; Ex. 1001. For claims of an expired patent, the Board’s claim construction analysis is similar to that of a district court. *See In re Rambus*, 694 F.3d 42, 46 (Fed. Cir. 2012). In this context, claim terms “are generally given their ordinary and customary meaning” as understood by a person of ordinary skill in the art in question at the time of the invention. *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312–13 (Fed. Cir. 2005) (en banc). “In determining the meaning of the disputed claim limitation, we look principally to the intrinsic evidence of record, examining the claim language itself, the written description, and the

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[2] K.S. Natarajan et al., *Medium Access Control Protocol for Wireless LANs (An Update)*, IEEE P802.11/92-39, Mar. 9, 1992 (Ex. 1011, “Natarajan 1992”).
[3] U.S. Patent No. 4,542,499, issued Sept. 17, 1985 (Ex. 1026, “Bella”).
[4] U.S. Patent No. 5,241,542, issued Aug. 31, 1993 (Ex. 1003, “Natarajan ’542”).
[5] U.S. Patent No. 5,123,029, issued June 16, 1992 (Ex. 1014, “Bantz”).

prosecution history, if in evidence." *DePuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.*, 469 F.3d 1005, 1014 (Fed. Cir. 2006) (citing *Phillips*, 415 F.3d at 1312–17).

1. "repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames"

Each challenged claim includes the following limitation, referred to by the parties as the "each" limitation: "repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames." *E.g.*, Ex. 1001, 46:29–31 (claim 6). In the Decision on Institution, we construed this claim limitation "to require that each communication cycle include intervals during which the hub and remotes are allowed to transmit and receive, without requiring actual transmission of frames." Dec. 12. We based our construction on the language of the claims, including additional language referring to "intervals . . . when the hub is *allowed to* transmit frames to the remotes [and] when the remotes are *allowed to* transmit frames to the hub." *Id.* at 10 (citing Ex. 1001, 46:36–39). We also considered the written description of the '542 patent, which speaks of transmission opportunities during which remotes are provided an opportunity to transmit messages to the hub. *Id.* (citing Ex. 1001, 12:14–17).

After institution, Patent Owner argued that this *inter partes* review turns on a single claim construction issue—whether the recited limitation "requires that, in each communication cycle, there be at least one interval in which a remote transmits frames to the hub, or whether there need only be an 'opportunity' for such transmission." PO Resp. 1 (emphasis omitted). In advocating for the former construction, Patent Owner relied on the district

court's holding in *Atlas v. Medtronic* that "[t]he plain meaning necessitates the hub and the remotes transmit and receive frames during each communication cycle, not that the hub and the remotes simply *may* do so during a communication cycle as Medtronic argues." *Atlas IP, LLC v. Medtronic, Inc.*, No. 1:13-cv-23309, 2014 WL 5305577, at *3 (S.D. Fla. Oct. 15, 2014); *see* PO Resp. 2.

After the oral hearing in this proceeding, the Federal Circuit addressed the proper construction of the "each" limitation in claims of the '734 patent. On appeal from summary judgment in the *Medtronic* case, the Federal Circuit rejected the district court's so-called "plain meaning" construction, also urged by Patent Owner here. *Medtronic*, 2015 WL 6550622, at *10. Instead, the Federal Circuit determined that context was necessary to resolve the facial uncertainty of the claim language. *Id.* at *8. The court analyzed the relevant contextual evidence, including the additional claim language and references to transmission opportunities in the written description that we cited in our claim construction discussion in the Decision on Institution. *Id.* at *9. With analysis similar to ours, the Federal Circuit held, as we did, that the claim language, properly construed, requires only that each cycle have one or more intervals in which remotes are allowed to transmit frames. *Id.*

Thus, the Federal Circuit, in a precedential opinion, rejected the same "plain meaning" claim construction argument made by Patent Owner in this proceeding. Also, as in this proceeding, Patent Owner provided no extrinsic evidence, so the court construed the disputed limitation based on intrinsic evidence—the claim language and the written description. Moreover, the court used the same *Phillips*-based claim construction approach that the

Board applies when a patent has expired. Accordingly, in our patentability analysis we will apply the Federal Circuit's construction of the "each" limitation, which, with respect to transmission by remotes, requires only that each cycle have one or more intervals during which remotes are *allowed* to transmit.

2. "the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle"

Each challenged claim includes the following limitation: "the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle." *E.g.*, Ex. 1001, 46:32–35 (claim 6). Petitioner proposed that this "transmitting" limitation be construed as "the hub transmitting to the remotes information necessary to know *in advance* the starting time and duration for the communication cycle and the plurality of predesignated intervals during each communication cycle." Pet. 19 (emphasis added). We did not construe this limitation expressly in the Decision on Institution, and Patent Owner did not propose a construction in either the Preliminary Response or the Patent Owner Response. Indeed, the "transmitting" limitation was not a point of contention during the trial, as the parties maintained that the proceeding turned on the correct construction of the "each" limitation and whether the prior art disclosed that limitation. *See* PO Resp. 1; Reply 1.

The "transmitting" limitation, however, was at issue in the two district court non-infringement summary judgment rulings reviewed by the Federal Circuit. In *Medtronic*, the Federal Circuit construed the "transmitting" limitation (in conjunction with "the hub establishing repeating

communication cycles") to "require the hub to define and transmit the start time and duration of each communication cycle and its constituent intervals *in advance*," i.e., before the transmission opportunities for the remotes begin. *Medtronic*, 2015 WL 6550622, at *6 (emphasis added). In *St. Jude*, vacating summary judgment of non-infringement under the district court's erroneous construction, the Federal Circuit further held that the "transmitting" limitation "does not require that the cycle's starting time and duration be communicated to the remotes even earlier, *i.e.*, before the communication cycle begins." *St. Jude*, 804 F.3d at 1188.

The Federal Circuit's construction of the "transmitting" limitation is consistent with that proffered by Petitioner in this proceeding in that both constructions require the hub to transmit the start time and duration of the communication cycle and its constituent intervals in advance. The Federal Circuit's opinions clarify that start time and duration must be transmitted "in advance" of the time at which the remotes may begin transmitting, but need not be transmitted "in advance" of the communication cycle. Because the Federal Circuit construed the "transmitting" limitation in precedential opinions under the same claim construction standard the Board uses for expired patents, we will apply the court's construction of the "transmitting" limitation in our patentability analysis.

3. "frame"

The parties do not dispute the proper construction of the claim term "frame," which we construed in the Decision on Institution as "an ordered group of bits, such as a packet, used to carry information between network stations." Dec. 9. We address this term here only to highlight that "frame" is used in the '734 patent in a manner different from how it is used in some

of the prior art. *Id.* (citing Pet. 16). Specifically, a “frame” in Natarajan 1992 and Natarajan ’542 is similar to a “communication cycle” in the ’734 patent, whereas a data “packet” in Natarajan 1992 and Natarajan ’542 is equivalent to a “frame” in the ’734 patent. *Id.* (citing Pet. 16); *see* Ex. 1002 ¶ 99.

B. Anticipation by Natarajan 1992—Claims 6, 14, and 21

Petitioner contends that claims 6, 14, and 21 are unpatentable under 35 U.S.C. § 102(a) as anticipated by Natarajan 1992, relying on declaration testimony of Dr. Zygmunt Haas. Pet. 20–34 (citing Ex. 1002 ¶¶ 78–147). Patent Owner responds, arguing only that under the proper claim construction, Natarajan 1992 does not disclose the “each” limitation. PO Resp. 5–7. Having considered the parties’ contentions and supporting evidence, we determine that Petitioner has demonstrated by a preponderance of the evidence that claims 6, 14, and 21 are unpatentable as anticipated by Natarajan 1992.

1. Natarajan 1992

Natarajan 1992 describes a MAC protocol for wireless local area networks (LANs). Ex. 1011, 1. The network architecture includes a finite number of Access Points through which mobile stations communicate. *Id.* at 2. Inbound and outbound communication between an Access Point and mobile stations is structured as a sequence of frames. *Id.* at 3. Figure 1 shows the frame structure of the MAC protocol described in Natarajan 1992:

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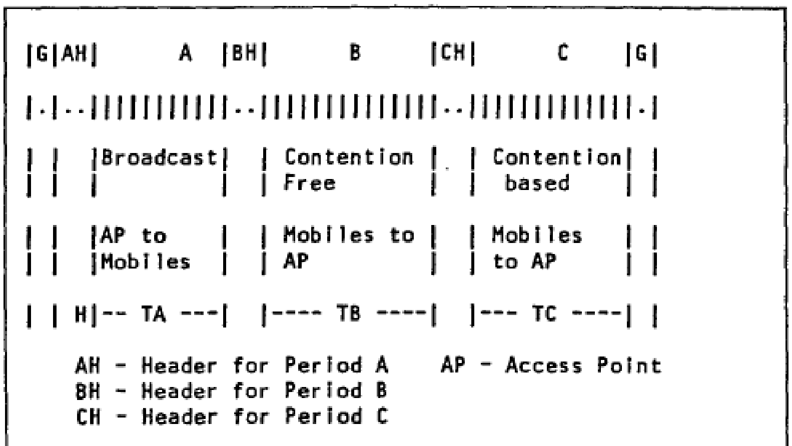


Figure 1. Frame Structure of Medium Access Control Scheme

Id. at 3. As shown in Figure 1, a frame contains three time intervals—Periods A, B, and C. *Id.* In the first interval (Period A), outbound traffic is transmitted from the Access Point to mobile stations. *Id.* In the second interval (Period B), bandwidth is allocated for contention-free inbound data transmitted from mobile stations to the Access Point. *Id.* The third interval (Period C) is used for contention-based transmission from mobile stations to the Access Point. *Id.* During this interval, mobile stations can submit requests for bandwidth in subsequent frames. *Id.* at 7.

Immediately before each of Periods A, B, and C, the Access Point broadcasts control information to the mobile stations in a header, shown as AH, BH, and CH in Figure 1. *Id.* at 4. Header AH identifies the start of the information frame and contains, among other control data, the lengths of Periods A, B, and C (TA, TB, and TC in Figure 1), as well as the lengths of Headers AH, BH, and CH (TAH, TBH, and TCH). *Id.* (Fig. 2 showing control information in Header AH). These parameters inform the mobile stations how much time is allocated to each of the intervals and headers in the current frame. *Id.* at 4–5. The lengths of the intervals are adjusted to enable bandwidth to be allocated on a demand-driven basis. *Id.* at 6.

Header AH also includes a list of mobile stations that will receive data packets from the Access Point during Period A. *Id.* at 4–5. On correct reception of Header AH, each mobile station can determine whether it will receive packets from the Access Point during Period A. *Id.* at 5. A mobile station that does not expect to receive data during Period A can power down its receiver at the beginning of Period A, and set a timer to power on the receiver at the end of Period A, just in time to receive Header BH. *Id.* at 20.

Header BH identifies the beginning of Period B. *Id.* at 5. The control information in Header BH includes a list of ordered pairs indicating the mobile stations that are allowed to transmit data packets to the Access Point during Period B, and the number of time slots in Period B allocated to each mobile station. *Id.* at 5–6. Based on the information in Header BH, a mobile station can determine whether it has been allocated slots during Period B and will power on its transmitter and transmit packets according to the ordered slot allocation information. *Id.* at 6, 20.

2. Limitations Common to Claims 6, 14, and 21

We begin our anticipation analysis with the limitations that independent claims 6, 14, and 21 have in common. Natarajan 1992 discloses a "communicator" (i.e., mobile station or Access Point) for wirelessly transmitting to and receiving "frames" (i.e., packets) from an "additional communicator" (i.e., mobile station or Access Point) "in accordance with a predetermined medium access control protocol" (i.e., a MAC protocol for wireless LANs). Ex. 1011, 3; *see* Pet. 21–22; Ex. 1002 ¶¶ 98–99. Natarajan 1992 also discloses communicators "constituting a Group," e.g., two mobile stations registered with the same Access Point, as shown in Figure 7. Ex. 1011, 10; *see* Pet. 22–23; Ex. 1002 ¶¶ 102–03. Each of

Natarajan 1992's communicators (i.e., mobile stations and Access Points) includes "a transmitter and a receiver for transmitting and receiving frames respectively." *See* Ex. 1011, 20 (mobile stations have transmitters and receivers); *id.* at 12 (mobile station units can be Access Points); Pet. 23; Ex. 1002 ¶¶ 105–06. The MAC protocol disclosed in Natarajan 1992 "designat[es] one of the communicators of the Group as a hub and the remaining communicators of the Group as remotes" when it explicitly designates a mobile station to provide the control functions of an Access Point, leaving the remaining mobile stations to act as remotes. Ex. 1011, 12; *see* Pet. 24; Ex. 1002 ¶¶ 109–14; Ex. 1001, 10:39–41 (the '734 patent indicating that communicators other than the hub are designated as remotes).

Natarajan 1992 also discloses the "each" limitation. In the MAC protocol described in Natarajan 1992, the "hub establish[es] repeating communication cycles" (i.e., sequences of frames having the structure shown in Figure 1 of Natarajan 1992). Ex. 1011, 3; *see* Pet. 26; Ex. 1002 ¶¶ 115–16. Each communication cycle (frame) has "intervals" during which the hub transmits frames received by the remotes—Period A (the period for outbound traffic from the Access Point to the mobile stations), as well as Headers AH, BH, and CH. Ex. 1011, 4–6; *see* Pet. 26–27; Ex. 1002 ¶ 117.

With respect to transmission by the remotes, the proper construction of the "each" limitation requires only that each cycle have one or more intervals during which remotes are *allowed* to transmit. *See supra* Section II.A.1. Period B is such an interval, as it contains allocated slots during which individual mobile stations are allowed to transmit packets to the Access Point. *See* Ex. 1011, 5–6; Pet. 27; Ex. 1002 ¶ 118. The individual slots within Period B are also intervals. *See* Pet. 27; Ex. 1002

¶ 122. Patent Owner's argument that Period B is not an interval meeting the requirements of the claim is unpersuasive because it is premised on an incorrect claim construction requiring at least one interval in which a remote actually transmits to the hub. *See* PO Resp. 5–7. As explained previously, the Federal Circuit has rejected Patent Owner's proffered construction of the "each" limitation. *See supra* Section II.A.1.

The MAC protocol described in Natarajan 1992 also satisfies the "transmitting" limitation. As construed by the Federal Circuit, this limitation requires the hub to define and transmit the start time and duration of each communication cycle and its constituent intervals before the time at which the remotes may begin transmitting. *See supra* Section II.A.2. Additional claim language requires that the intervals be "ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub." *E.g.*, Ex. 1001, 46:36–40 (claim 6).

First, Natarajan 1992 discloses the three different types of intervals recited in the "transmitting" limitation. Period A and Headers AH, BH, and CH are intervals when the hub (Access Point) is allowed to transmit to the remotes (mobile stations). Ex. 1011, 4–6; *see* Pet. 29; Ex. 1002 ¶¶ 124–25. Period B and its individual slots are intervals when the remotes (mobile stations) are allowed to transmit to the hub (Access Point). Ex. 1011, 5; *see* Pet. 29; Ex. 1002 ¶ 126. Headers AH, BH, and CH are intervals when each remote is expected to receive a frame from the hub (i.e., when the Access Point broadcasts control information to the mobile stations). Ex. 1011, 4–6; *see* Pet. 29–30; Ex. 1002 ¶ 127.

Next, Natarajan 1992's hub (Access Point) defines and transmits the start time and duration of a communication cycle (frame) before the transmission opportunities for the remotes (mobile stations) begin. Specifically, Header AH, transmitted by the Access Point to the mobile stations at the beginning of a frame, includes parameters identifying the lengths of Periods A, B, and C (i.e., TA, TB, and TC) and the lengths of Headers AH, BH, and CH (i.e., TAH, TBH, and TCH). Ex. 1011, 4–5; *see* Pet. 27–28; Ex. 1002 ¶¶ 119–20. According to Natarajan 1992, Header AH identifies the start of the information frame, and the information contained therein (i.e., TA, TB, TC, TAH, TBH, and TCH) tells the mobile stations the duration of the frame. Ex. 1011, 4–5; *see* Pet. 27–28; Ex. 1002 ¶ 120. The Access Point broadcasts Header AH prior to the time at which the remotes may begin transmitting, which occurs during Period B. *See* Ex. 1011, 3 (Fig. 1).

The Access Point in Natarajan 1992 also defines and transmits the start time and duration of the intervals in the communication cycle (frame) prior to the time at which the remotes may begin transmitting. As noted, Header AH, transmitted at the beginning of the frame, contains the timing information for Periods A, B, and C and for Headers AH, BH, and CH. Ex. 1011, 4–5; *see* Pet. 27–28; Ex. 1002 ¶¶ 119–20. In addition, Header BH contains the timing information for the individual slots in Period B in the form of an ordered list of mobile stations and the number of slots allocated to each mobile station, allowing each mobile station to know when and for how long it may transmit to the Access Point. Ex. 1011, 5–6; *see* Pet. 28; Ex. 1002 ¶ 122. Header BH is sent immediately before Period B, and thus is transmitted before the first remotes (mobile stations) are permitted to

transmit. *See* Ex. 1011, 3 (Fig. 1). Because the Access Point transmits the start time and duration of the frame and all relevant intervals—Periods A, B, and C; Headers AH, BH, and CH; and the individual slots in Period B—before the transmission opportunities for the mobile stations begin, Natarajan 1992 discloses the "transmitting" limitation as construed by the Federal Circuit.

In supplemental briefing that we authorized after the Federal Circuit decided the *Medtronic* and *St. Jude* appeals, Patent Owner contends Petitioner did not account for the Federal Circuit's construction of the "transmitting" limitation in its unpatentability analysis. Paper 25, 5. We are not persuaded by Patent Owner's argument. The Petition, with ample citation to Natarajan 1992 and to Dr. Haas's testimony for support, provided a detailed explanation of when the hub (Access Point) in Natarajan 1992 transmits the start time and duration of both the communication cycle (frame) and its constituent intervals. *See* Pet. 26–29 (citing Ex. 1002 ¶¶ 115–23). As discussed above, Natarajan 1992's Access Point transmits all the relevant timing information in advance of the time at which the remotes (mobile stations) may begin transmitting (i.e., Period B), which is all that is required under the Federal Circuit's construction of the "transmitting" limitation. For purposes of determining whether Natarajan 1992 anticipates, it is immaterial that the "transmitting" limitation does not require the timing information to be transmitted even earlier, i.e., before the communication cycle begins.

Finally, Natarajan 1992 discloses the remotes (mobile stations) "powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames [and] powering off their receivers

during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub." As set forth in Natarajan 1992, a mobile station uses knowledge of receiver and transmitter schedules, based on the information transmitted from the hub in Headers AH, BH, and CH, to minimize power consumption "when the mobile station is neither actively transmitting nor actively receiving information." Ex. 1011, 20; *see* Pet. 30; Ex. 1002 ¶¶ 129–33. More specifically, a mobile station turns its transmitter off except (i) during the slots allocated to the mobile station for transmission during Period B according to the information received in Header BH, and (ii) if the mobile station wishes to transmit during contention-based Period C. Ex. 1011, 20. Similarly, a mobile station turns its receiver off except (i) when it expects to receive Headers AH, BH, and CH, and (ii) during Period A if the mobile station is in Header AH's list of mobile stations that will receive data during Period A. *Id.*; *see* Ex. 1002 ¶ 132.

3. Remaining Limitations in Claims 6, 14, and 21

In addition to the limitations that appear in all of the challenged claims, Natarajan 1992 discloses the remaining limitations recited in claims 6, 14, and 21. First, as recited in claim 6, Natarajan 1992 discloses "the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub" (i.e., the slots allocated in Period B for mobile stations to transmit to the Access Point). Ex. 1011, 5–6; *see* Pet. 31. Natarajan 1992 also discloses "the hub transmitting transmission opportunity allocation information in a frame transmitted by the hub" (i.e., slot allocation information transmitted to the mobile stations in Header BH). Ex. 1011, 5–6; *see* Pet. 31. Lastly, with

respect to "the hub allocating a number of transmission opportunities during at least one communication cycle which is at least one less in number than the number of remotes in the Group," Natarajan 1992 explains that some mobile stations do not have allocated slots in Period B during a particular frame (i.e., do not have transmission opportunities) and put their receivers to sleep for the entire length of Period B. Ex. 1011, 20; *see* Pet. 31–32; Ex. 1002 ¶¶ 136–37.

Natarajan 1992 also discloses the additional limitations in claim 14 (Ex. 1001, 49:63–68): "the hub establishing the length of each communication cycle" (i.e., the lengths of Periods A, B, and C, and lengths of headers AH, BH, and CH) and "the hub transmitting a frame containing information describing the length of the communication cycle prior to the end of the communication cycle whose length is established" (i.e., Header AH, sent at the beginning of a frame, containing the lengths of Periods A, B, and C, and lengths of headers AH, BH, and CH). Ex. 1011, 4 (Fig. 2); *see* Pet. 32–33; Ex. 1002 ¶¶ 140–44.

Finally, Natarajan 1992 discloses "the hub transmitting two frames containing information to establish the plurality of predeterminable intervals during each communication cycle," as recited in claim 21. *See* Ex. 1001, 51:3–9. Header AH is a first frame containing timing information for Periods A, B, and C, and for Headers AH, BH, and CH. Ex. 1011, 4–5; *see* Pet. 33; Ex. 1002 ¶ 146. Header BH is a second frame containing timing information for the allocated slots in Period B. Ex. 1011, 5–6; *see* Pet. 33; Ex. 1002 ¶ 146. The second frame (Header BH) also "occur[s] before the intervals in which the remotes are allowed to transmit frames to the hub," as

required by claim 21, because it is transmitted before Period B. Ex. 1011, 3 (Fig. 1); *see* Pet. 34; Ex. 1002 ¶ 147.

4. Conclusion

For the foregoing reasons, we determine that Petitioner has shown by a preponderance of the evidence that claims 6, 14, and 21 are anticipated by Natarajan 1992.

C. Obviousness over Natarajan 1992 and Bella—Claim 11

Petitioner contends that claim 11 is unpatentable under 35 U.S.C. § 103(a) over the combination of Natarajan 1992 and Bella, relying on declaration testimony of Dr. Haas. Pet. 34–38 (citing Ex. 1002 ¶¶ 148–67). With regard to this ground and the other asserted obviousness grounds, Patent Owner argues only that none of the cited prior art teaches the "each" limitation under the district court's construction, which the Federal Circuit has rejected. *See* PO Resp. 7–8. As discussed in the previous section, Natarajan 1992 discloses the "each" limitation under the proper claim construction.

In addition to reciting limitations included in claim 6, claim 11 requires the hub to "monitor[] the frames transmitted by each remote during its transmission opportunity" and to "revok[e] a previous transmission opportunity allocation of a remote which has not transmitted more than a predetermined number of frames during a previous number of communication cycles." Ex. 1001, 48:31–36. For the reasons explained below, we are persuaded by Petitioner's argument that the combination of Natarajan 1992 and Bella teaches these additional limitations and that a person of ordinary skill in the art would have combined the references in the manner asserted. *See* Pet. 34–38.

Bella describes a system for medium access control in a LAN that carries data and voice traffic. Ex. 1026, 1:9–16; *see* Ex. 1002 ¶ 150. Bella's system combines contention-based communications with TDMA-like time slots that may be reserved for voice traffic. Ex. 1026, 2:3–34, 3:10–31; *see* Pet. 35; Ex. 1002 ¶¶ 153–54. A communicator device that has voice traffic to transmit sends a booking packet to reserve a time slot during which it will regularly transmit speech packets. Ex. 1026, 3:65–4:2, 9:50–55; *see* Ex. 1002 ¶ 154. This reservation persists until it is cancelled. Ex. 1026, 10:26–33; *see* Pet. 35; Ex. 1002 ¶ 154. Cancellation occurs when the communicator device that has reserved the time slot stops transmitting packets, so the time slot passes unused. Ex. 1026, 11:9–13; *see* Pet. 35; Ex. 1002 ¶ 155. Other stations monitor packets transmitted on the network and interpret the lack of packets in the time slot as a cancellation of the reservation. Ex. 1026, 11:9–13; *see* Pet. 35; Ex. 1002 ¶ 155.

Petitioner relies on a combination of Bella's time slot cancellation method with the system of Natarajan 1992 to satisfy the additional limitations of claim 11. Pet. 34–38; Ex. 1002 ¶¶ 161–67. Like Bella, Natarajan 1992 describes a system in which mobile stations make reservation requests for slot allocation. Ex. 1011, 7–8; *see* Pet. 37–38; Ex. 1002 ¶ 165. If a mobile station requests isochronous service, the requested number of slots will be allocated to the mobile station in Period B of every frame until the mobile station cancels the allocation by sending a cancellation request. Ex. 1011, 8; *see* Pet. 36, 38; Ex. 1002 ¶ 166. Thus, Natarajan 1992 teaches "revoking a previous transmission opportunity allocation of a remote," as recited in claim 11, when the hub receives a cancellation request from the remote. *See* Pet. 37–38; Ex. 1002 ¶ 166–67. If

the system of Natarajan 1992 instead utilized Bella's cancellation method, which revokes a previous transmission allocation when a remote transmits no packets in a communication cycle, we are persuaded by Petitioner's argument that the combination would result in "the hub revoking a previous transmission opportunity allocation of a remote which has not transmitted more than a predetermined number of frames" (zero) "during a previous number of communication cycles" (one). *See* Pet. 37–38; Ex. 1002 ¶ 167. Furthermore, if Natarajan 1992 employed the cancellation technique of Bella, the hub would be "monitoring the frames transmitted by each remote during its transmission opportunity." *See* Pet. 37; Ex. 1002 ¶¶ 162, 164.

Petitioner also has articulated sufficient reasoning with some rational underpinning to support the legal conclusion that the subject matter of claim 11 would have been obvious to one of ordinary skill in the art in view of the combined teachings of the references. *See KSR Int'l Co. v. Teleflex, Inc.*, 550 U.S. 398, 418 (2007); Pet. 35–37; Ex. 1002 ¶¶ 156–60. According to Petitioner, for example, the combination would simplify the cancellation method of Natarajan 1992 by allowing the hub to revoke a time slot allocation when the remote stops transmitting. Pet. 36; Ex. 1002 ¶ 158. Relying on Dr. Haas's testimony for support, Petitioner also asserts that using Bella's cancellation method makes even more sense when the remotes are mobile, as in Natarajan 1992, because they may move outside of the hub's range abruptly and be unable to cancel their own reservations. Pet. 37; Ex. 1002 ¶ 159. Moreover, we are persuaded by Petitioner's position that only ordinary skill would be required to implement the reservation and cancellation method of Bella in the Natarajan 1992 system. *See* Pet. 37; Ex. 1002 ¶ 160.

For these reasons, having considered the parties' contentions and supporting evidence, we determine that Petitioner has shown by a preponderance of the evidence that claim 11 would have been obvious over the combination of Natarajan 1992 and Bella.

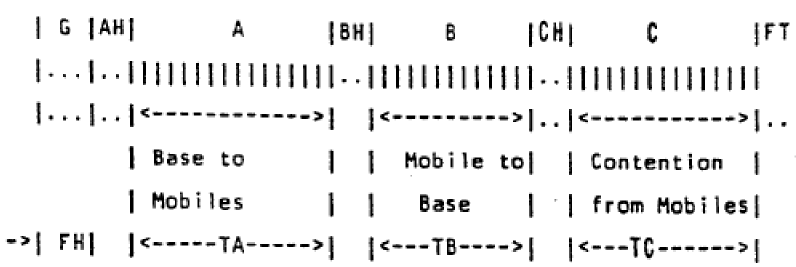
D. Obviousness over Natarajan '542 and Bantz—Claims 6, 14, and 21

Petitioner contends that claims 6, 14, and 21 are unpatentable under 35 U.S.C. § 103(a) over Natarajan '542 and Bantz, relying on declaration testimony of Dr. Haas. Pet. 43–58 (citing Ex. 1002 ¶¶ 195–257). In response, Patent Owner contends only that Natarajan '542 does not disclose the "each" limitation for the same reasons argued with respect to Natarajan 1992. PO Resp. 7.

1. Natarajan '542

As Petitioner notes, Natarajan '542 is a United States patent describing Natarajan's work and is similar in substance to Natarajan 1992. Ex. 1003; *see* Pet. 43. Figure 4 illustrates the frame structure of the MAC protocol described in Natarajan '542:

FIG. 4



Ex. 1003, Fig. 4. As shown in Figure 4, a frame contains three time intervals—Periods A, B, and C—just as in Natarajan 1992. *Id.* at 4:28–38. Period A is for outbound traffic from a base station to mobile stations; Period B is for contention-free inbound traffic from mobile stations to the

base station; and Period C is for contention-based inbound traffic. *Id.* As in Natarajan 1992, immediately preceding each interval is a header containing control information from which a mobile station can determine when to power on and off its transmitter and receiver. *Id.* at 4:41–5:60. Header BH contains an ordered list of mobile stations that are allowed to transmit data packets to the base station during Period B and the bandwidth allocated to each mobile station. *Id.* at 5:9–19.

2. Bantz

Bantz, which shares a co-inventor with Natarajan '542, describes a MAC protocol for use in wireless networks. Ex. 1014. Like Natarajan '542, Bantz describes a frame (or communication cycle) with intervals for inbound and outbound traffic between a base station and mobile stations. *See id.* at Fig. 3A. Of particular note is Bantz's teaching that the protocol described therein "may be implemented in a distributed file system composed of only remote stations, one of which is designated as a base station. Moreover, the designation of the base station can be made to be dynamic . . . ."
Id. at 11:53–57.

3. Analysis

Petitioner contends that Natarajan '542 teaches most of the limitations of claims 6, 14, and 21. Pet. 47–58. Petitioner's detailed analysis is similar to that presented with respect to anticipation of these claims by Natarajan 1992, a substantially similar reference. *Id.* The one exception is that Petitioner relies on Bantz for teaching the "designating" limitation recited in each of claims 6, 14, and 21. *Id.* at 44, 49. We agree with Petitioner that Bantz teaches designating a "hub" (i.e., base station that coordinates and relays communications between mobile stations) and

designating the remaining mobile stations as "remotes." Ex. 1014, 4:1–18, 11:50–62; *see* Pet. 49; Ex. 1002 ¶¶ 224–25. We also are persuaded by Petitioner's analysis that Natarajan '542 discloses the remaining limitations of claims 6, 14, and 21, including the "each" limitation and "transmitting" limitation as properly construed, for reasons similar to those explained with respect to anticipation by Natarajan 1992. *See* Pet. 47–58.

Moreover, we are persuaded that Petitioner has provided sufficient reasoning with some rational underpinning to support the conclusion of obviousness based on the combination of Natarajan '542 and Bantz, which Petitioner describes as "the incorporation of known techniques (those of Bantz) for their known functions with a known base system (described in Natarajan '542), without unpredictable results." *Id.* at 46–47 (citing *KSR*, 550 U.S. at 415–20); *see* Ex. 1002 ¶¶ 209–10. For example, Bantz teaches that the ability to designate a base station dynamically is advantageous in the event that a currently designated base station should fail, a feature that would have been desirable in the network disclosed in the related Natarajan '542 reference. *See* Ex. 1014, 11:52–61; Pet. 44–45; Ex. 1002 ¶¶ 203–04.

Having considered the parties' contentions and supporting evidence, we determine that Petitioner has shown by a preponderance of the evidence that claims 6, 14, and 21 would have been obvious over the combination of Natarajan '542 and Bantz.

E. Obviousness over Natarajan '542, Bantz, and Bella—Claim 11

Petitioner contends that claim 11 is unpatentable under 35 U.S.C. § 103(a) over the combination of Natarajan '542, Bantz, and Bella, relying on declaration testimony of Dr. Haas. Pet. 58–59; *see* Ex. 1002 ¶¶ 262–69.

Patent Owner makes no additional arguments directed specifically to this asserted ground. *See* PO Resp. 7–8.

For reasons discussed in the previous two sections, Natarajan ’542 teaches most of the limitations of claim 11, except for the “designating” limitation (taught by Bantz) and the “monitoring” and “revoking” limitations (taught by the combination of Natarajan ’542 and Bella). *See* Pet. 58–59. Also for reasons discussed previously, Petitioner has articulated sufficient reasoning with some rational underpinning to support a conclusion of obviousness in view of the combined teachings of the references. *See id.* As Petitioner points out, the only material difference between Natarajan ’542 and Natarajan 1992 is that although Natarajan ’542 discloses mobile stations sending bandwidth requests to the base station, it does not expressly disclose requests for isochronous service, in which bandwidth is reserved in all future frames until cancelled. *See* Pet. 58; Ex. 1002 ¶ 262; Ex. 1003, 5:63–64. Nevertheless, Petitioner contends, with support from Dr. Haas, that carrying voice and other isochronous traffic would have been desirable in the relevant timeframe, so that it would have been obvious to add the capability to Natarajan ’542 by using booking packets as taught by Bella, combined with Bella’s method for cancelling, or revoking, the reservation. *See* Pet. 58–59; Ex. 1002 ¶¶ 262–64.

Having considered the parties’ contentions and supporting evidence, we determine that Petitioner has shown by a preponderance of the evidence that claim 11 would have been obvious over the combination of Natarajan ’542, Bantz, and Bella.

III. CONCLUSION

Based on the evidence and arguments, Petitioner has demonstrated by a preponderance of the evidence that (i) claims 6, 14, and 21 of the ’734 patent are anticipated by Natarajan 1992, (ii) claim 11 is unpatentable for obviousness over the combination of Natarajan 1992 and Bella; (iii) claims 6, 14, and 21 are unpatentable for obviousness over the combination of Natarajan ’542 and Bantz; and (iv) claim 11 is unpatentable for obviousness over the combination of Natarajan ’542, Bantz, and Bella.

IV. ORDER

Accordingly, it is:

ORDERED that claims 6, 11, 14, and 21 of U.S. Patent No. 5,371,734 have been shown to be unpatentable.

This is a final written decision. Parties to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ST. JUDE MEDICAL, INC., ST. JUDE MEDICAL S.C., INC.,
PACESETTER, INC., and BIOTRONIK, INC.,
Petitioner,

v.

ATLAS IP LLC,
Patent Owner.

Case IPR2014-00916[1]
Patent 5,371,734

Before BARBARA A. BENOIT, LYNNE E. PETTIGREW, and GEORGIANNA W. BRADEN, *Administrative Patent Judges*.

PETTIGREW, *Administrative Patent Judge*.

DECISION
Patent Owner's Request for Rehearing
37 C.F.R. § 42.71

In a Final Written Decision, we determined that St. Jude Medical, Inc., St. Jude Medical S.C., Inc., Pacesetter, Inc., and Biotronik, Inc.

[1] Case IPR2015-00534 has been joined with this proceeding.

(collectively, "Petitioner") had shown by a preponderance of the evidence that claims 6, 11, 14, and 21 ("the challenged claims") of U.S. Patent No. 5,371,734 (Ex. 1001, "the '734 patent") are unpatentable. Paper 29 ("Decision" or "Dec."). Atlas IP LLC ("Patent Owner") requests rehearing of that decision. Paper 30 ("Rehearing Request" or "Reh'g Req."). We grant rehearing for the purpose of considering Patent Owner's arguments, but we decline to modify our determination that the challenged claims are unpatentable.

I. BACKGROUND

St. Jude Medical, Inc., St. Jude Medical S.C., Inc., and Pacesetter, Inc. filed a Petition for *inter partes* review of claims 6, 11, 14, 21, and 44 of the '734 patent. Paper 2 ("Pet."). We instituted an *inter partes* review of claims 6, 11, 14, and 21 of the '734 patent on asserted grounds of unpatentability. Paper 7. Subsequent to institution, Biotronik, Inc. was joined as a petitioner in this review. Paper 17. Thereafter, Patent Owner filed a Patent Owner Response to the Petition, Paper 16 ("PO Resp."), and Petitioner filed a Reply to the Patent Owner Response, Paper 18 ("Pet. Reply"). An oral hearing was held on July 15, 2015.[2]

On October 29, 2015, after the oral hearing but prior to a Final Written Decision in this case, the United States Court of Appeals for the Federal Circuit issued precedential opinions in appeals from decisions in two district court cases involving the '734 patent. *See Atlas IP, LLC v. Medtronic, Inc.*, 809 F.3d 599 (Fed. Cir. 2015) ("*Medtronic*"); *Atlas IP, LLC v. St. Jude Med., Inc.*, 804 F.3d 1185 (Fed. Cir. 2015) ("*St. Jude*"). Pursuant

[2] A transcript of the hearing was entered into the record. Paper 22 ("Tr.").

to our authorization, the parties filed supplemental briefing addressing the impact of the Federal Circuit's *Medtronic* and *St. Jude* opinions on this proceeding. Papers 24, 25, 27.

In our Final Written Decision, we determined that Petitioner had shown by a preponderance of the evidence that (i) claims 6, 14, and 21 of the '734 patent are anticipated by Natarajan 1992;[3] (ii) claim 11 is unpatentable for obviousness over the combination of Natarajan 1992 and Bella;[4] (iii) claims 6, 14, and 21 are unpatentable for obviousness over the combination of Natarajan '542[5] and Bantz;[6] and (iv) claim 11 is unpatentable for obviousness over the combination of Natarajan '542, Bantz, and Bella. Dec. 13–28. Our Decision specifically addressed two claim limitations that appear in each of the challenged claims and were construed by the Federal Circuit in *Medtronic* and *St. Jude*—"repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames" (the "each" limitation) and "the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle" (the "transmitting" limitation). *Id.* at 8–12 (claim construction); *id.* at 16–20 (finding that Natarajan 1992 discloses the "each" limitation and the "transmitting" limitation); *id.* at 27 (finding that

[3] K.S. Natarajan et al., *Medium Access Control Protocol for Wireless LANs (An Update),* IEEE P802.11/92-39, Mar. 9, 1992 (Ex. 1011, "Natarajan 1992").
[4] U.S. Patent No. 4,542,499, issued Sept. 17, 1985 (Ex. 1026, "Bella").
[5] U.S. Patent No. 5,241,542, issued Aug. 31, 1993 (Ex. 1003, "Natarajan '542").
[6] U.S. Patent No. 5,123,029, issued June 16, 1992 (Ex. 1014, "Bantz").

Natarajan ’542 discloses the “each” limitation and the “transmitting” limitation for reasons similar to those explained with respect to Natarajan 1992). Because the ’734 patent had expired, we applied the Federal Circuit’s district court-type claim construction of the “each” limitation and “transmitting” limitation in our analysis of the asserted anticipation and obviousness grounds. *Id.* at 8–12.

Patent Owner now requests rehearing of our Final Written Decision. *See* Reh’g Req. 1. Pursuant to our authorization, *see* Paper 31, Petitioner filed an opposition to Patent Owner’s Rehearing Request, Paper 32 (“Reh’g Opp.”), and Patent Owner filed a reply in support of its Rehearing Request, Paper 33 (“Reh’g Reply”).

II. DISCUSSION

A. Standard for Rehearing

The party challenging a decision in a request for rehearing bears the burden of showing the decision should be modified. 37 C.F.R. § 42.71(d). A request for rehearing “must specifically identify all matters the party believes the Board misapprehended or overlooked, and the place where each matter was previously addressed.” *Id.*

Patent Owner’s arguments in its Rehearing Request primarily relate to the “transmitting” limitation. We explained in our Decision that the “transmitting” limitation was not a point of contention during the trial, as the parties maintained in their initial briefing and at the oral hearing that the proceeding turned on the correction construction of the “each” limitation and whether the prior art disclosed that limitation. Dec. 11; *see* PO Resp. 1; Pet. Reply 1; Tr. 4:8–16, 18:10–14. After the hearing, however, the Federal Circuit addressed the proper construction of both the “each” limitation and

the "transmitting" limitation in the '734 patent. *See* Dec. 10–12; *Medtronic*, 809 F.3d at 605–10; *St. Jude*, 804 F.3d at 1188–90. We then authorized the parties to submit supplemental briefing to address the impact of the *Medtronic* and *St. Jude* Federal Circuit opinions on this proceeding. Paper 23. While Petitioner directed its brief to the "each" limitation, Paper 24, Patent Owner argued for the first time in this proceeding that the prior art does not disclose the "transmitting" limitation and contended that Petitioner did not account for the Federal Circuit's construction of the "transmitting" limitation in its unpatentability analysis, Paper 25, 5. In our Final Written Decision, we disagreed with Patent Owner's argument and found that Natarajan 1992 discloses the "transmitting" limitation.[7] Dec. 17–19.

Patent Owner argues that it previously addressed, in its supplemental submission regarding the Federal Circuit opinions, the issues regarding the "transmitting" limitation it raises now in its Rehearing Request. Reh'g Req. 12; Reh'g Reply 6. Patent Owner further argues that rehearing is warranted under 37 C.F.R. § 42.71(d) because the page limit placed on supplemental briefing was insufficient to provide a full opportunity for

[7] We also found that Natarajan '542 discloses the "transmitting" limitation. Dec. 27. As discussed in our Decision, Natarajan '542 is substantially similar to Natarajan 1992 and discloses most of the claim limitations, including the "each" and "transmitting" limitations, for reasons similar to those explained in connection with Natarajan 1992. *Id.* The Rehearing Request does not distinguish between Natarajan 1992 and Natarajan '542. *See* Reh'g Req. 4 (referring to the "Natarajan References" or "Natarajan"). Accordingly, in this decision we refer to Natarajan 1992 (Ex. 1011) when addressing the parties' arguments, though our analysis applies equally to Natarajan '542.

Patent Owner to address the Federal Circuit's construction of the "transmitting" limitation. Reh'g Req. 12–13; Reh'g Reply 6. In response, Petitioner contends that the Rehearing Request contains improper new arguments that could have been presented in the Patent Owner Response because the Federal Circuit's construction was consistent with, or broader than, the construction proposed in the Petition. Reh'g Opp. 9–10. Petitioner further contends that the issue raised by Patent Owner in its supplemental submission regarding the effect of the Federal Circuit opinions was much more limited than the arguments made in the Rehearing Request. *Id.* at 10.

We largely agree with Petitioner. As stated in our Decision, the Federal Circuit's construction of the "transmitting" limitation is consistent with that proffered by Petitioner in this proceeding, and the Petition explained in detail how Natarajan 1992's Access Point (corresponding to the claimed hub) transmits the start time and duration of the communication cycle and a plurality of predeterminable intervals in advance of the time the remotes may begin transmitting, as required under the Federal Circuit's claim construction. Dec. 12, 19. Thus, Patent Owner could have addressed the "transmitting" limitation in its Patent Owner Response. Furthermore, we agree that the arguments regarding the "transmitting" limitation in the Rehearing Request are more extensive than those in Patent Owner's earlier supplemental submission.

Nevertheless, in light of the unusual circumstances of this case, in which the Federal Circuit construed limitations of the claims at issue after the oral hearing, we consider in this decision the arguments regarding the "transmitting" limitation raised in the Rehearing Request, as well as those in Petitioner's opposition and Patent Owner's reply. We do so out of an

abundance of caution to ensure that the parties have had a fair and sufficient opportunity to present arguments addressing the Federal Circuit's claim construction, which we applied in our Final Written Decision. *See SAS Inst., Inc. v. ComplementSoft, LLC*, 825 F.3d 1341, 1351 (Fed. Cir. 2016); *Dell Inc. v. Acceleron, LLC*, 818 F.3d 1293, 1301 (Fed. Cir. 2016). We also consider herein the related arguments directed to the additional limitation in claim 21 requiring the hub to "transmit[] two frames containing information to establish the plurality of predeterminable intervals." Ex. 1001, 51:3–5; *see* Reh'g Req. 12; Reh'g Opp. 6–9; Reh'g Reply 4–5.

B. The "Transmitting" Limitation

Patent Owner argues first that Natarajan 1992 does not disclose the "transmitting" limitation because the remotes do not have "complete information" about an entire communication cycle until after they have been allowed to transmit to the hub due to the "unique information" about the communication cycle contained in Header CH. Reh'g Req. 10. As Petitioner points out, however, the only information that must be transmitted to the remotes before the time at which they may begin transmitting is "the starting time and duration of the cycle and of remote-transmission intervals within each cycle." *St. Jude*, 804 F.3d at 1188; *see* Dec. 11–12; Reh'g Opp. 3. In reply, Patent Owner concedes that only the starting time and duration of the cycle and intervals must be transmitted. Reh'g Reply 2. But, Patent Owner continues, the claim language requires transmitting starting time and duration for *all* intervals in the communication cycle. *Id.* at 2–4.

We agree with Petitioner that, contrary to Patent Owner's argument, the "transmitting" limitation does not require that the hub transmit timing information about *all* possible intervals in a communication cycle. *See*

Reh'g Opp. 4–5. The claim language requires the hub to transmit information to establish (i.e., the starting time and duration of) the communication cycle and a plurality of (i.e., two or more) predeterminable intervals during each communication cycle, the intervals being ones [1] "when the hub is allowed to transmit frames to the remotes" (outbound intervals), [2] "when the remotes are allowed to transmit frames to the hub" (inbound intervals), and [3] "when each remote is expected to receive a frame from the hub" (outbound intervals). *E.g.*, Ex. 1001, 46:36–40 (claim 6). Thus, the "transmitting" limitation only requires the hub to transmit starting time and duration of the communication cycle and at least two intervals of types [1]–[3]. *See* Reh'g Opp. 4–5. Note that intervals of types [1] and [3] "presumably are not mutually exclusive" because they are both outbound intervals in which the hub transmits to the remotes. *Medtronic*, 809 F.3d at 609; *see* Reh'g Opp. 2–3.

As we determined in our Decision, Natarajan 1992 meets all the requirements of the "transmitting" limitation as properly construed. Dec. 17–19. First, Header AH, transmitted from the hub to the remotes, identifies the start of a communication cycle and contains TAH, TBH, and TCH (the lengths of Headers AH, BH, and CH, respectively), and TA, TB, and TC (the lengths of Periods A, B, and C, respectively), which added together provide the duration of the entire communication cycle, consisting of back-to-back intervals AH, A, BH, B, CH, and C. Ex. 1011, 3–5; *see* Dec. 18; Pet. 27–28; Ex. 1002 ¶¶ 119–20. Second, Header AH identifies the start time and duration of intervals of type [1] (Period A and Headers AH, BH, and CH), type [2] (Period B), and type [3] (Headers AH, BH, and CH). Ex. 1011, 4–5; *see* Dec. 18; Pet. 27–28; Ex. 1002 ¶¶ 119–20. In addition,

Header BH contains the start time and duration of Period B and its constituent slots when individual remotes may transmit to the hub, all of which are type [2] inbound intervals. Ex. 1011, 5–6; *see* Dec. 18; Pet. 28; Ex. 1002 ¶ 122. Thus, Natarajan 1992's hub transmits all of the information required by the "transmitting" limitation—the starting time and duration of the communication cycle and the starting time and duration of a plurality of predeterminable intervals of types [1]–[3]. And because Headers AH and BH precede Period B in Natarajan 1992's communication cycle, all of the required information is sent *in advance* of the time the remotes may begin transmitting, as required under the correct claim construction.

Patent Owner's additional arguments, relating to Period C of Natarajan 1992, are without merit. *See* Reh'g Req. 10–11; Reh'g Reply 3–4. First, Patent Owner asserts that because the length of Period C can vary, the remotes do not have the requisite information about the communication cycle until they receive Header CH. Reh'g Req. 10; Reh'g Reply 4. This is incorrect. Even if the length of Period C can change from one communication cycle to another, the length of Period C (i.e., TC) for a particular communication cycle is transmitted initially as part of Header AH and then repeated in Headers BH and CH. Ex. 1011, 4–6, 9. Thus, as discussed above and in our Decision, all the information necessary for determining the duration of a communication cycle, including Period C, is transmitted in Header AH, in advance of the time the remotes may begin transmitting.

Second, Patent Owner argues that the analysis of the "transmitting" limitation in our Decision failed to account for the contention-based nature of Period C in Natarajan 1992. Reh'g Req. 10–11. According to Patent

Owner, the contention-based communication in Period C results in collisions of transmissions from multiple remotes, contrary to the requirements of the "transmitting" limitation, and is "antithetical to the invention claimed in the '734 patent." Reh'g Req. 3–5, 10–11. We agree with Petitioner that these arguments are irrelevant because neither the Petition nor our Decision cited Period C as one of the plurality of predeterminable intervals established by the "transmitting" limitation. *See* Reh'g Opp. 5; Pet. 28–30; Dec. 17–19. Moreover, as Petitioner points out, the embodiments of the communication cycle described in the '734 patent include a contention-based interval. *See* Reh'g Opp. 5. For example, the embodiment shown in Figure 3 of the '734 patent, reproduced in both our Decision and the Federal Circuit's *Medtronic* opinion, includes a contention-based inbound interval (Txop request interval 86), which, like Period C in Natarajan 1992, allows remotes to submit requests for transmission opportunities in the next communication cycle. Ex. 1001, Fig. 3, Ex. 1011, 6–7; *see Medtronic*, 809 F.3d at 602; Dec. 4; Reh'g Opp. 5–6. Finally, nothing in the Federal Circuit's construction of the "transmitting" limitation, which we applied in our Decision, excludes from the scope of the claims a communication cycle that has a contention-based interval. *See Medtronic*, 809 F.3d at 605–07; *St. Jude*, 804 F.3d at 1188–90; Dec. 11–12. Thus, the presence of Period C in Natarajan 1992's communication cycle does not affect our determination that Natarajan 1992 discloses the "transmitting" limitation as previously discussed.

B. Claim 21

Claim 21 recites an additional limitation not present in the other challenged claims: "the hub transmitting two frames containing information

to establish the plurality of predeterminable intervals during each communication cycle." Ex. 1001, 51:3–5. In the Decision, we found that Headers AH and BH in Natarajan 1992, cited in the Petition as satisfying this limitation, are the first and second frames required by claim 21. Dec. 21–22; Pet. 33–34. Patent Owner argues for the first time in the Rehearing Request that Headers AH and BH cannot be the two information frames of claim 21 because they are different, with Header AH containing information about Periods A, B, and C, and Header BH containing information only about Periods B and C. Reh'g Req. 12; Reh'g Reply 4–5.

We find Patent Owner's argument to be unpersuasive for the following reasons. First, like the "transmitting" limitation discussed above, claim 21 does not require either of the recited frames to send timing information about *all* intervals in a communication cycle. Rather, the two frames must transmit timing information (i.e., starting time and duration) for "the plurality of predeterminable intervals." Contrary to Patent Owner's argument, *see* Reh'g Req. 12, the antecedent basis for "the plurality of predeterminable intervals" is not "intervals" in the "each" limitation, but "a plurality of predeterminable intervals" in the "transmitting" limitation.

Second, Header BH contains the information required by the second frame. With respect to type [2] inbound intervals, Header BH provides the timing information to establish Period B. The end of Header BH signifies the start time of Period B, and Header BH also contains TB, the duration of Period B. Ex. 1011, 5–6; *see* Dec. 15; Reh'g Opp. 7–8; Pet. 33; Ex. 1002 ¶ 146. Header BH also provides timing information for type [1] and type [3] inbound intervals. The transmission of Header BH communicates both the start time and the duration of Header BH itself. Ex. 1011, 5; *see* Reh'g

Opp. 8. As noted above, Header BH is an interval of both type [1] and type [3]. Header BH also contains timing information to establish Header CH, another interval of both type [1] and type [3]. Specifically, Header BH contains the length of Period B (TB), which establishes the start time of Header CH (i.e., at the conclusion of Period B). Ex. 1011, 5; *see* Pet. 33; Ex. 1002 ¶ 146. Header BH also contains the length of Period C (TC). Ex. 1011, 5; Pet. 33; Ex. 1002 ¶ 146. As Petitioner asserts, the length of Header CH can be determined at the end of Header BH as the remaining duration of the communication cycle minus TB and TC. *See* Ex. 1011, 3; Reh'g Opp. 8–9.

Finally, we agree with Petitioner that nothing in claim 21 requires the two frames to be identical, as Patent Owner suggests. *See* Reh'g Opp. 9. Instead, the claim language at most requires both intervals to transmit the same information concerning the "plurality of predeterminable intervals." *See id*. Even if this is so, Headers AH and BH satisfy the limitation because both contain information for establishing Period B and Header BH, as well as Header CH. *See id.* It is of no moment that Header AH contains additional information.

III. CONCLUSION

Patent Owner's Rehearing Request is *granted* insofar as we have considered the arguments presented therein, but, for the reasons explained herein, we decline to modify our determination that the challenged claims are unpatentable.

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[45] **Date of Patent:** Dec. 6, 1994

[54] **MEDIUM ACCESS CONTROL PROTOCOL FOR WIRELESS NETWORK**

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[73] Assignee: **Digital Ocean, Inc.,** Overland Park, Kans.

[21] Appl. No.: **11,415**

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[51] **Int. Cl.**[5] **H04B 7/216; H04B 7/26**

[52] **U.S. Cl.** **370/18;** 370/95.1; 370/95.3; 340/825.47; 455/38.2; 455/54.2

[58] **Field of Search** 370/18, 95.1, 95.3; 340/825.44, 825.47; 455/38.2, 38.3, 53.1, 54.1, 54.2, 68, 69, 70

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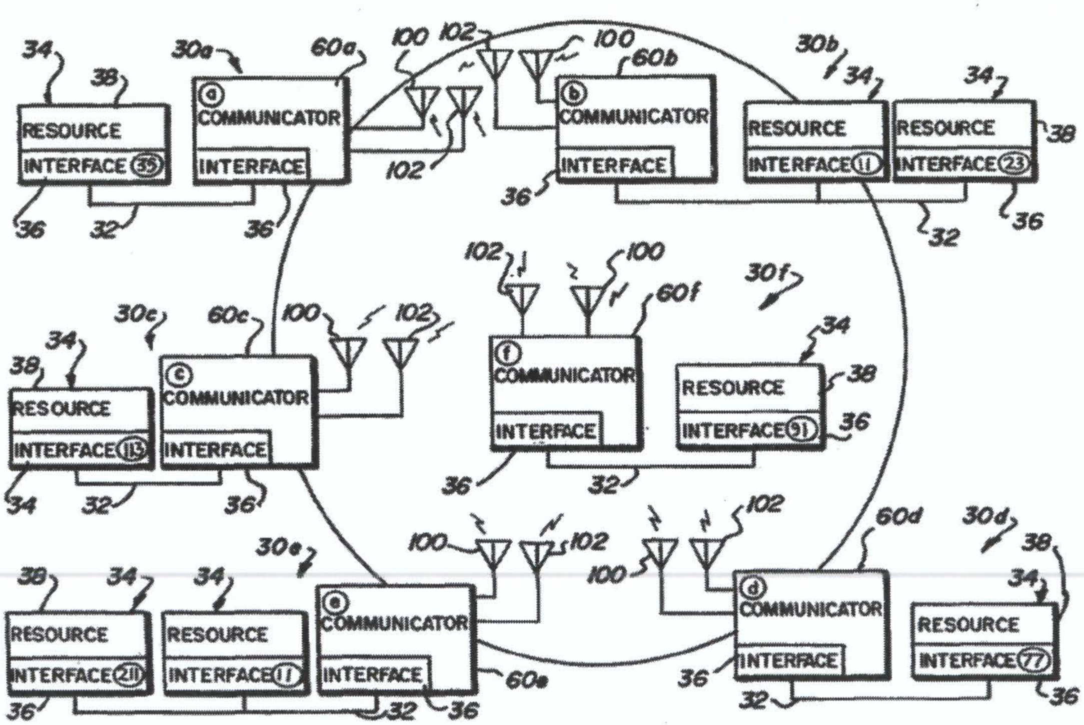
Primary Examiner—Wellington Chin

Attorney, Agent, or Firm—John R. Ley

[57] **ABSTRACT**

A communicator station wirelessly transmits frames to and receives frames from a least one additional communicator in a Group in accordance with a MAC protocol. One of the communicators functions as a hub and the remaining communicators function as remotes. The hub sends control information to the hubs to establish repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames. The intervals allow the hub and the remotes to anticipate transmitting and receiving frames, thereby allowing the remotes to power off their receivers and transmitters to achieve a considerable savings in power consumption without degrading communications. Other improved features include adjusting the intervals and the durations of transmission opportunities in the communication cycle to obtain the beneficial aspects of TDMA and PRMA for LAN-like communication without also incurring most of the undesirable aspects of such MAC techniques. Other control functions such as arbitration determine which communicator is better suited to act as the hub.

47 Claims, 12 Drawing Sheets



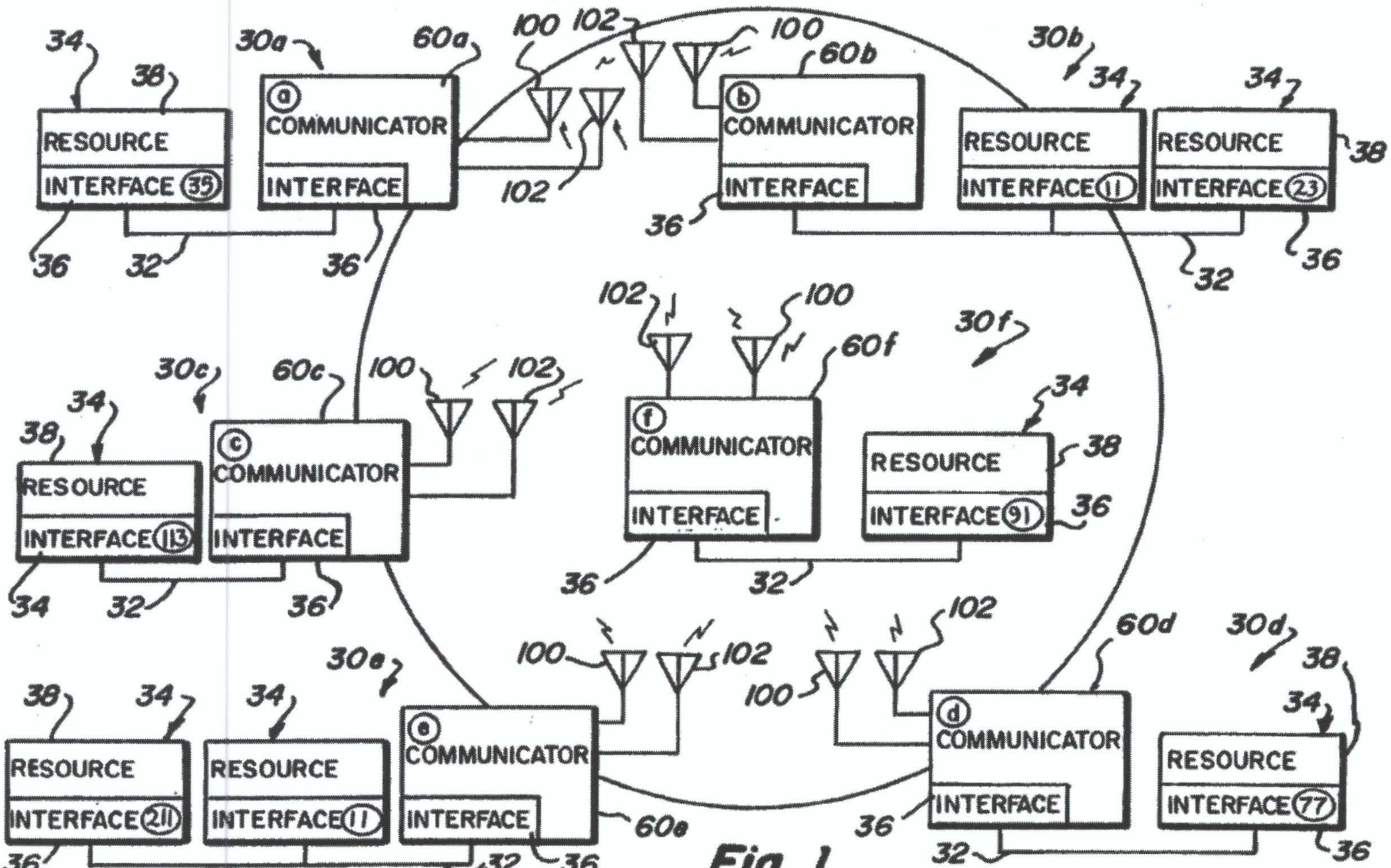

RESOURCE
INTERFACE 35
COMMUNICATOR
INTERFACE
COMMUNICATOR
INTERFACE
RESOURCE
INTERFACE 11
RESOURCE
INTERFACE 23
COMMUNICATOR
INTERFACE
RESOURCE
INTERFACE 91
RESOURCE
INTERFACE 113
COMMUNICATOR
INTERFACE
RESOURCE
INTERFACE 211
RESOURCE
INTERFACE 11
COMMUNICATOR
INTERFACE
COMMUNICATOR
INTERFACE
RESOURCE
INTERFACE 77

Fig_1

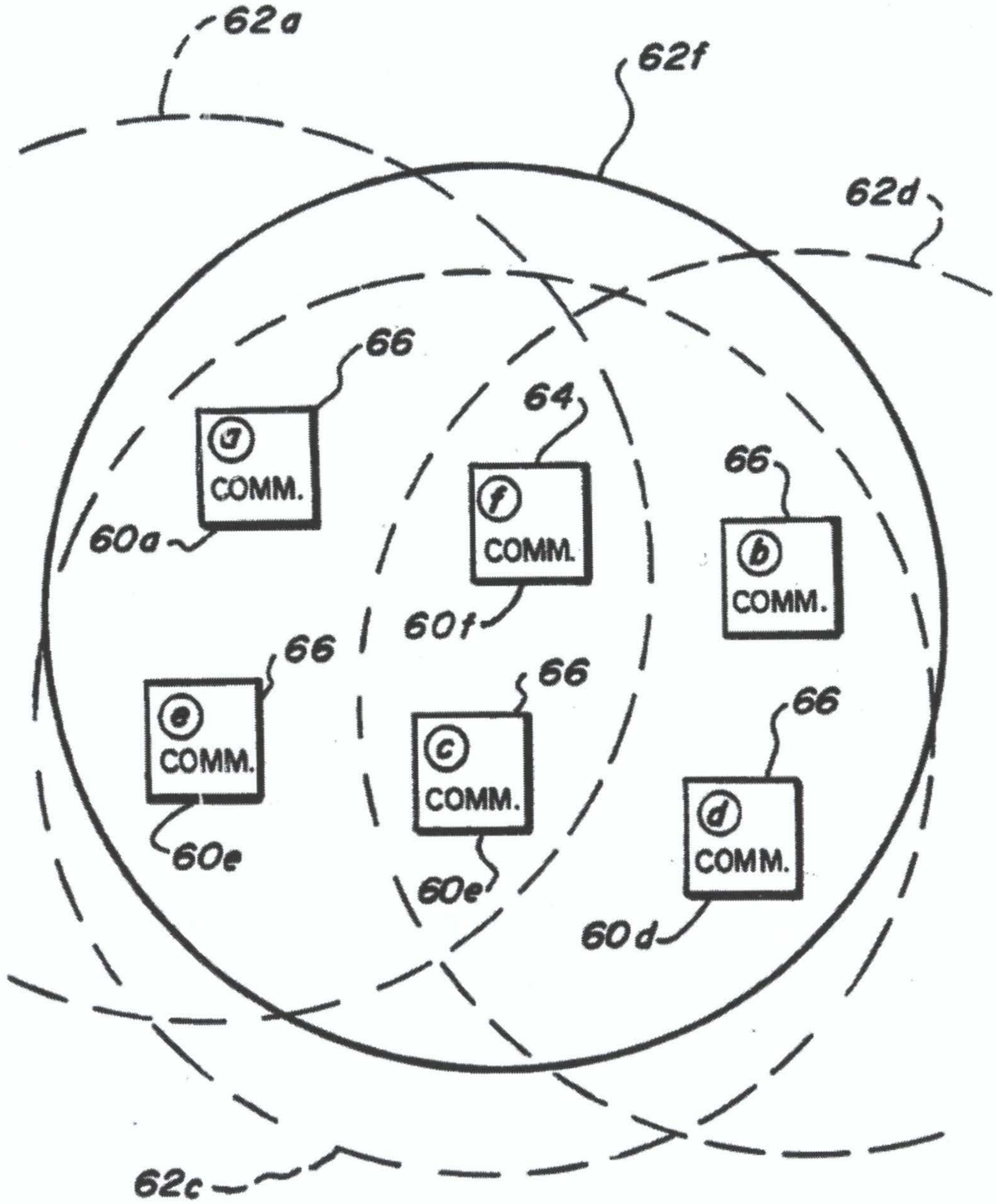

62a
62f
62d
66
64
66
66
66
66
66
60a
60f
60e
60e
60d
62c
a
COMM.
f
COMM.
b
COMM.
e
COMM.
c
COMM.
d
COMM.

Fig_2

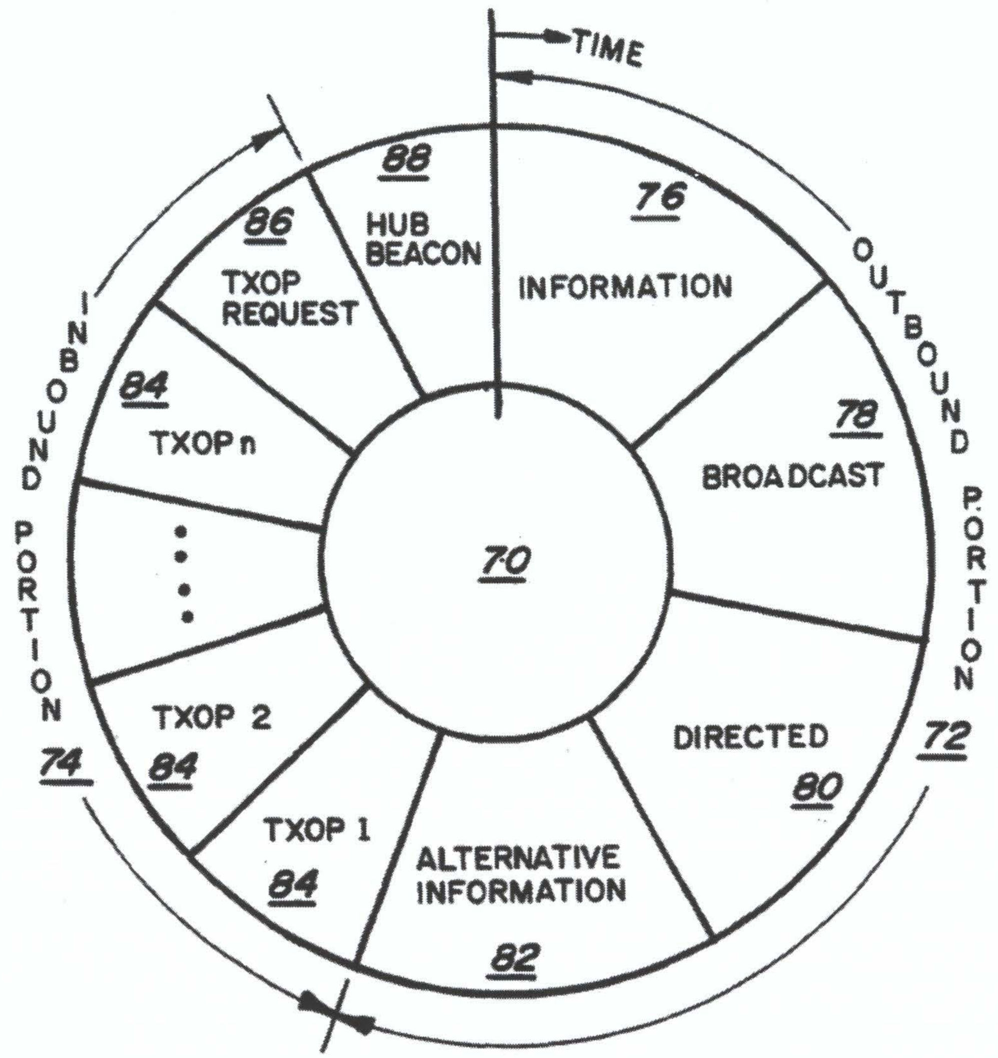
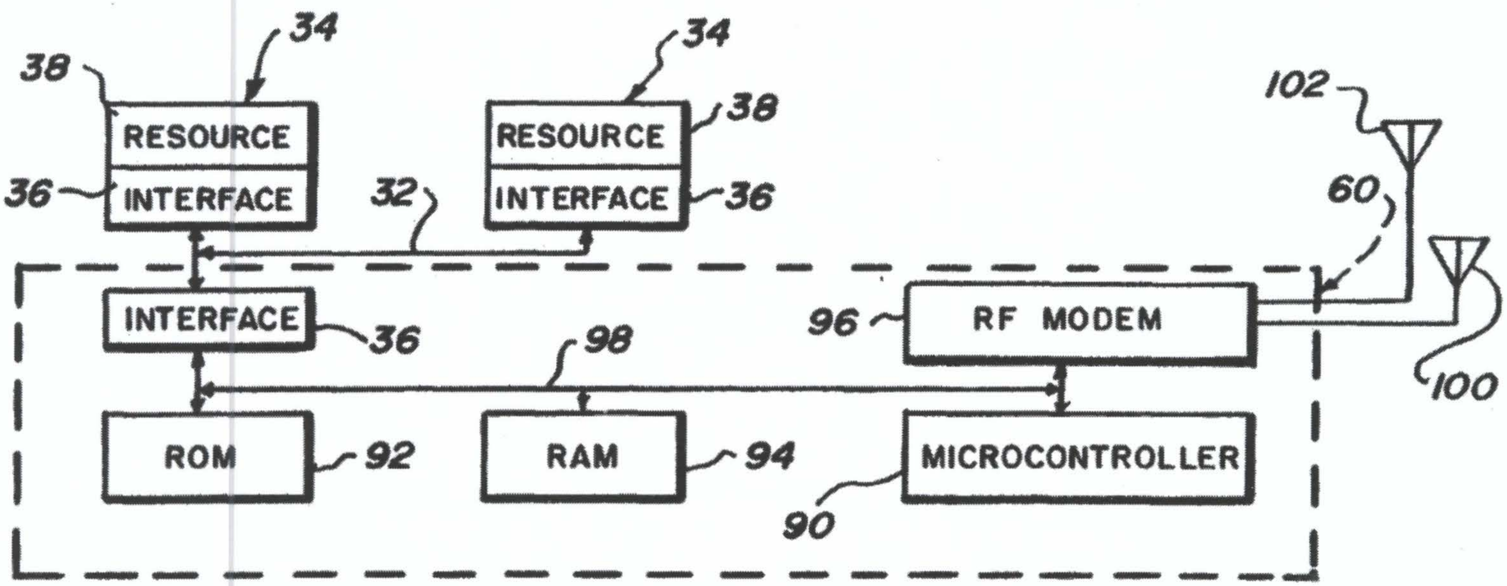

TIME
88
HUB BEACON
76
INFORMATION
OUTBOUND PORTION
78
BROADCAST
70
DIRECTED
80
72
ALTERNATIVE INFORMATION
82
TXOP 1
84
TXOP 2
84
74
TXOP n
84
86
TXOP REQUEST
INBOUND PORTION

Fig_3



38
34
RESOURCE
INTERFACE
36
34
38
RESOURCE
INTERFACE
36
32
102
60
INTERFACE
36
98
96
RF MODEM
100
ROM
92
RAM
94
MICROCONTROLLER
90

Fig_4

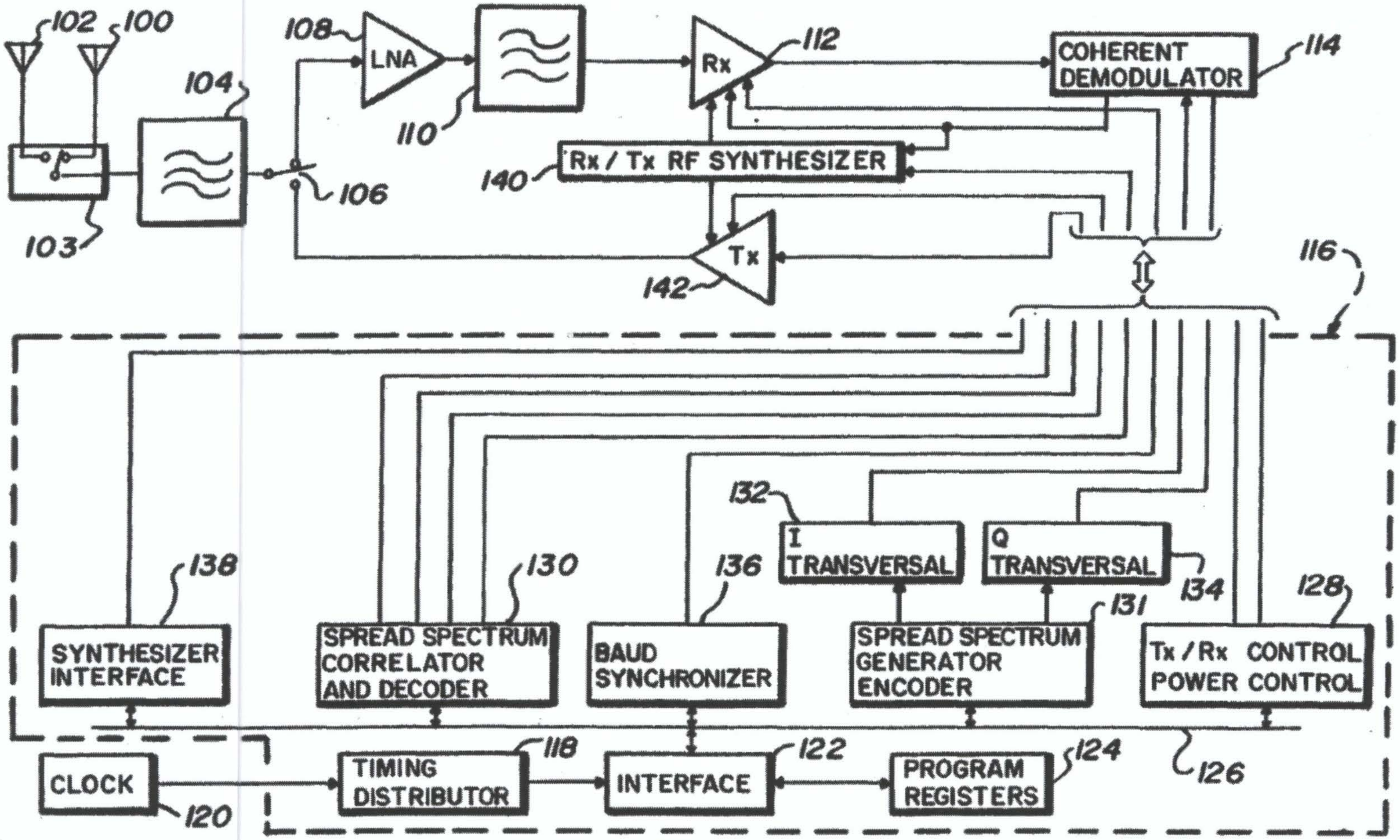

102
100
104
103
106
108
LNA
110
Rx
112
COHERENT DEMODULATOR
114
Rx / Tx RF SYNTHESIZER
140
Tx
142
116
132
I TRANSVERSAL
Q TRANSVERSAL
134
138
SYNTHESIZER INTERFACE
130
SPREAD SPECTRUM CORRELATOR AND DECODER
136
BAUD SYNCHRONIZER
131
SPREAD SPECTRUM GENERATOR ENCODER
128
Tx / Rx CONTROL POWER CONTROL
CLOCK
120
118
TIMING DISTRIBUTOR
122
INTERFACE
124
PROGRAM REGISTERS
126

Fig_5

Fig_6

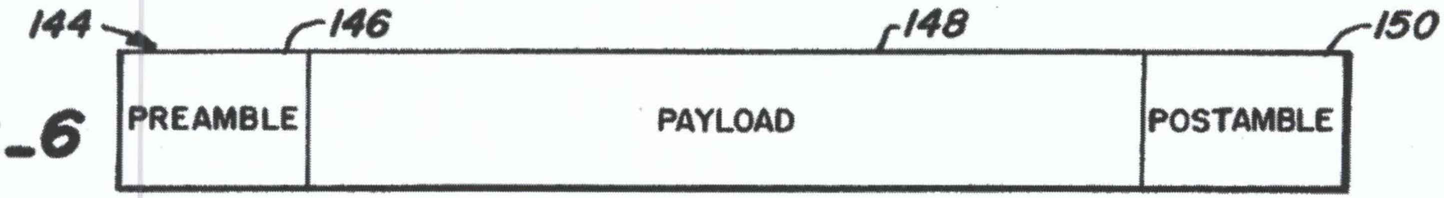


Fig_7

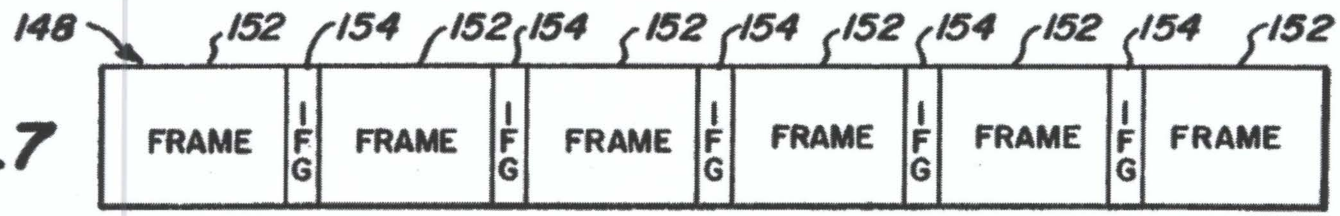


Fig_8

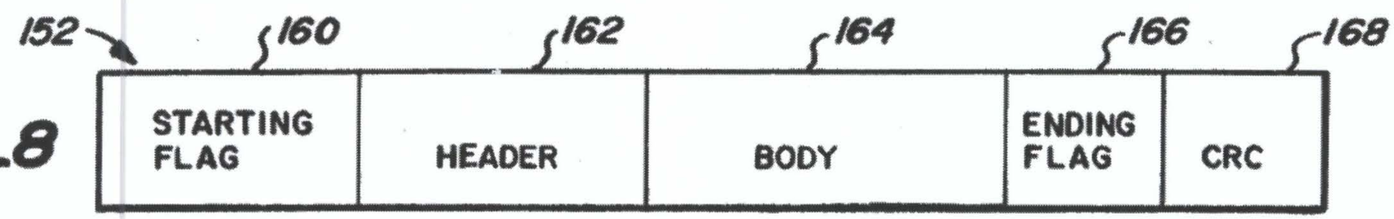
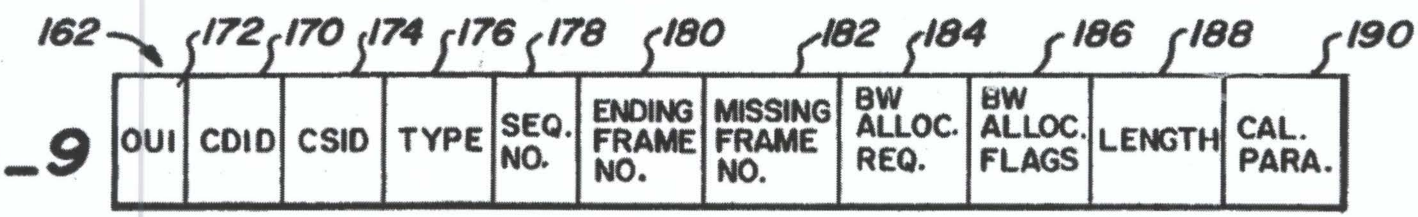


Fig_9



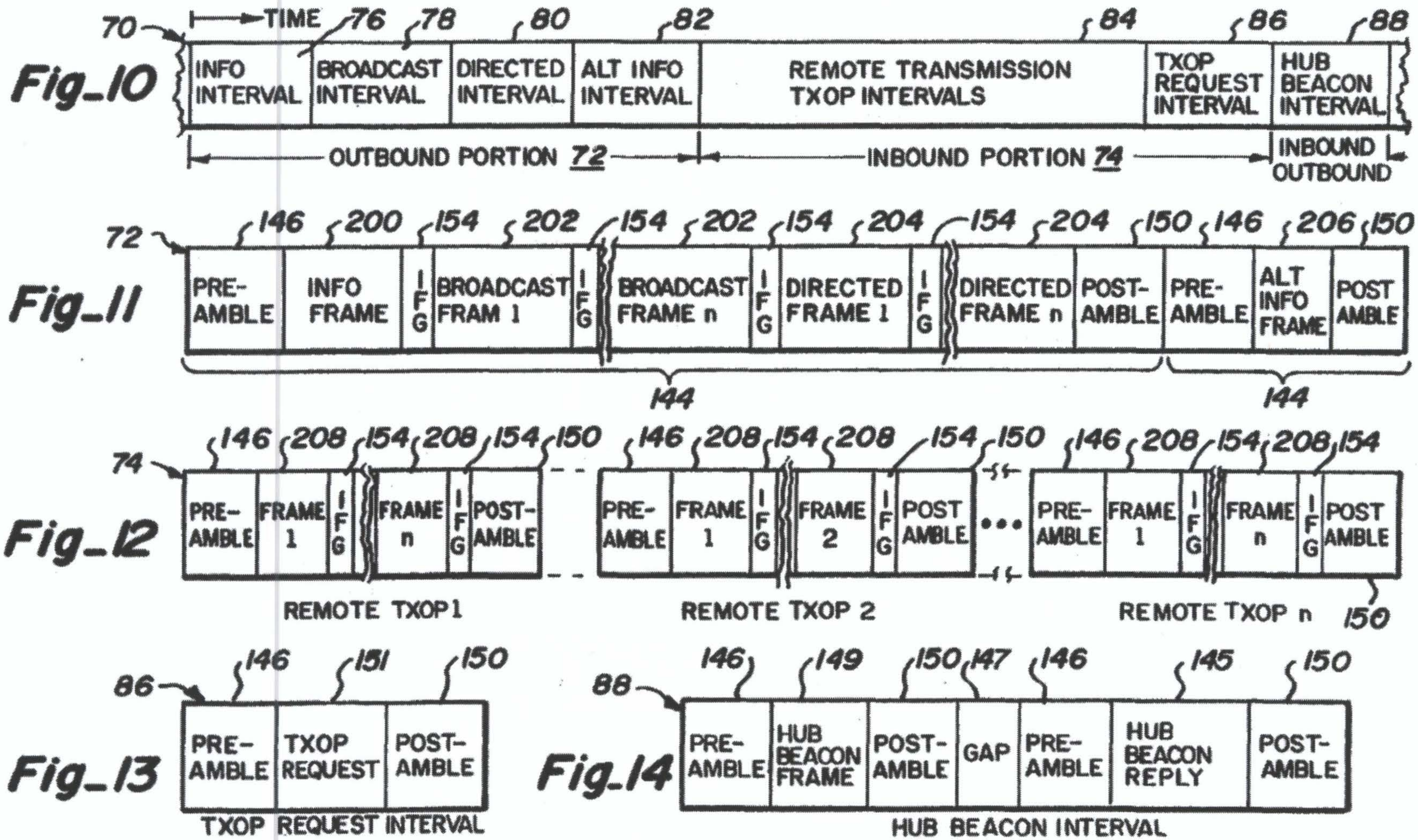


Fig_10

Fig_11

Fig_12

Fig_13

Fig_14

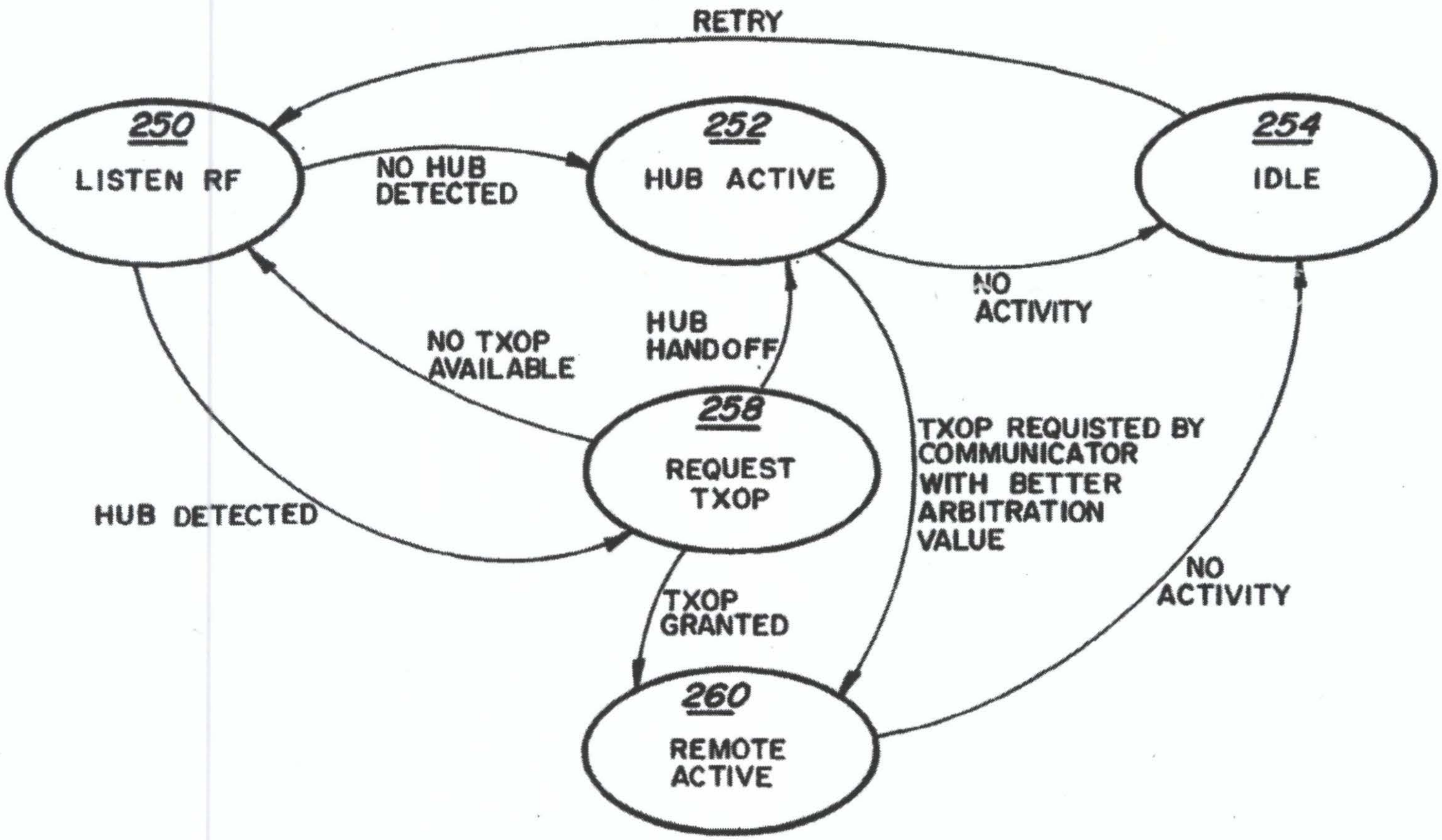

RETRY
250
LISTEN RF
NO HUB DETECTED
252
HUB ACTIVE
254
IDLE
NO ACTIVITY
NO TXOP AVAILABLE
HUB HANDOFF
258
REQUEST TXOP
TXOP REQUISTED BY COMMUNICATOR WITH BETTER ARBITRATION VALUE
HUB DETECTED
NO ACTIVITY
TXOP GRANTED
260
REMOTE ACTIVE

Fig_15

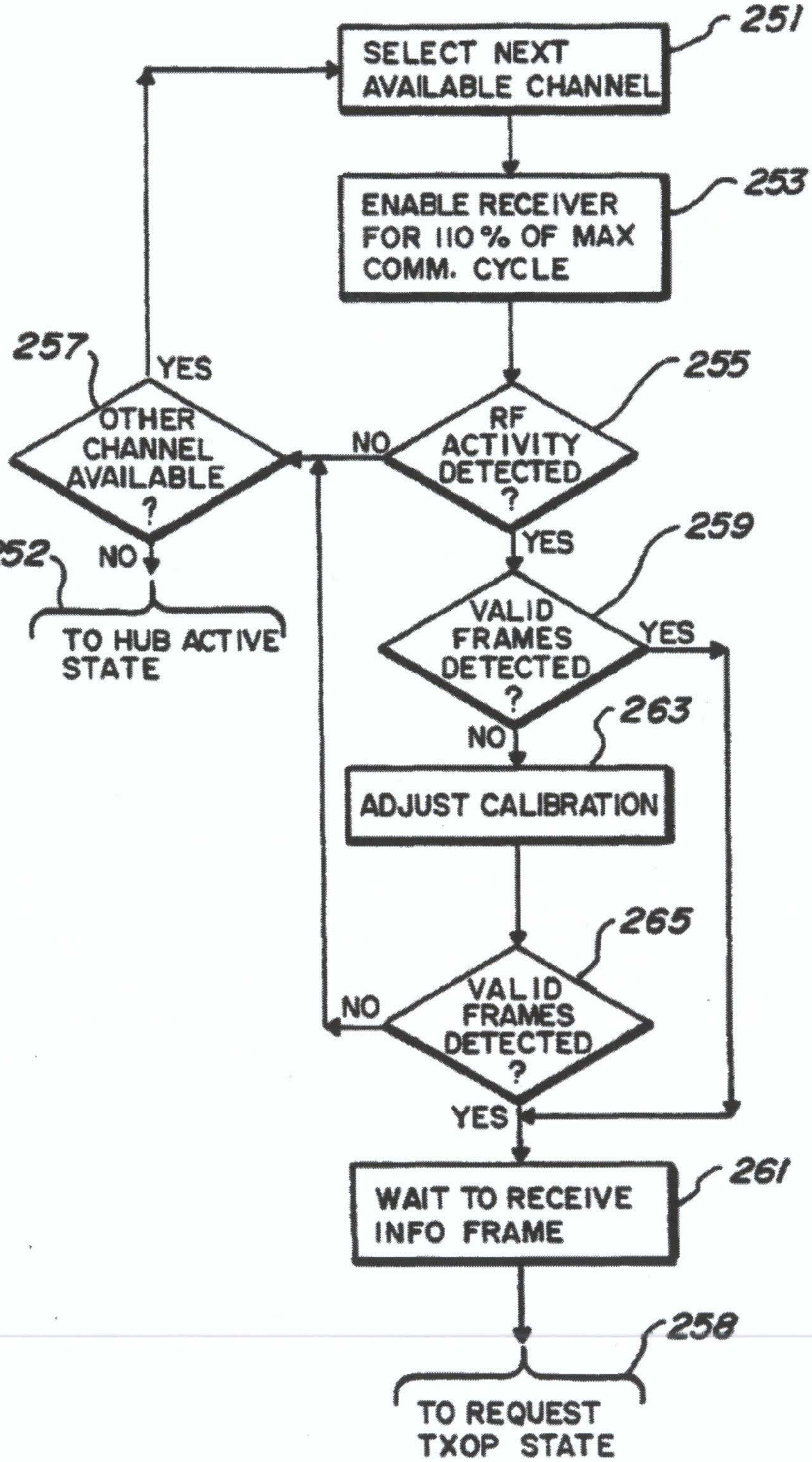
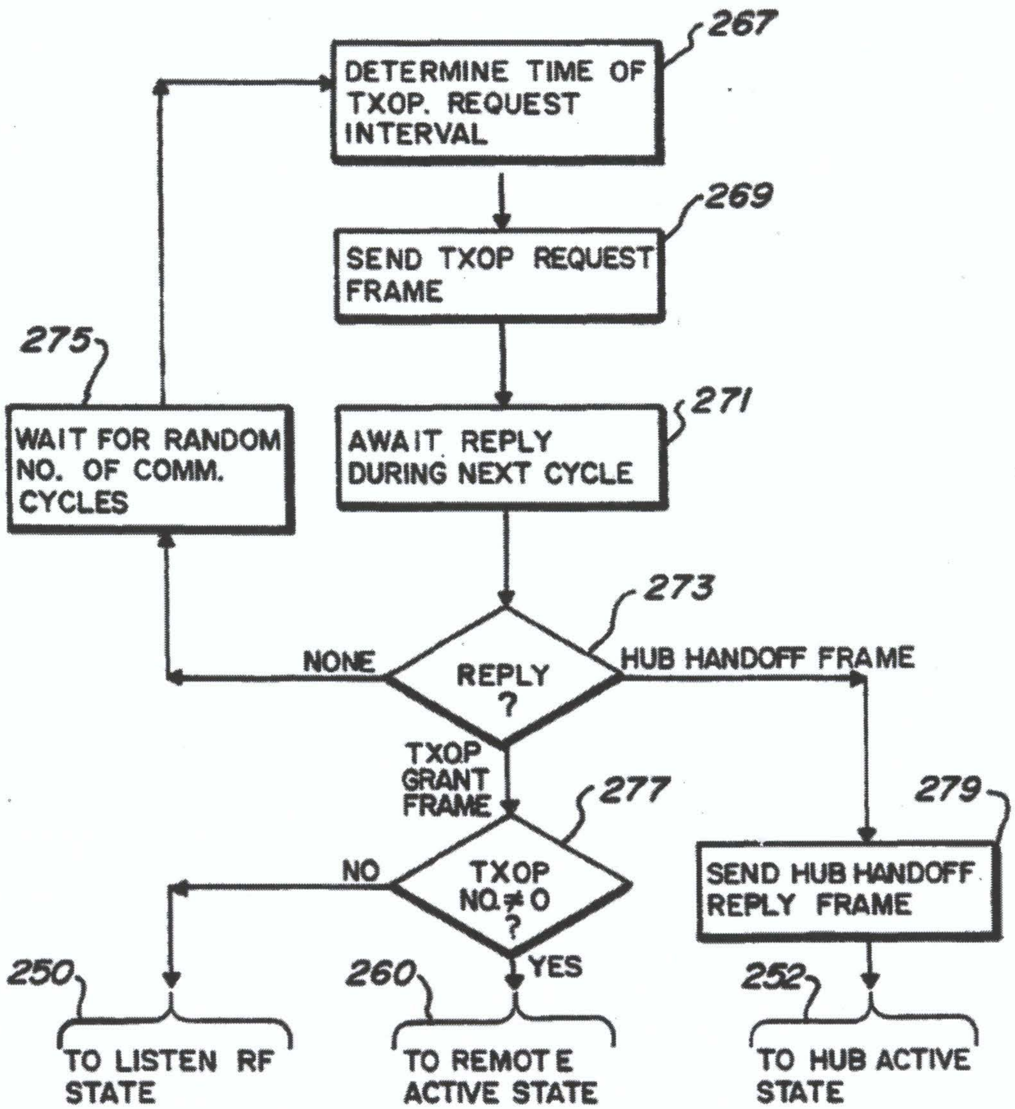

251
SELECT NEXT AVAILABLE CHANNEL
253
ENABLE RECEIVER FOR 110 % OF MAX COMM. CYCLE
257
YES
OTHER CHANNEL AVAILABLE ?
NO
255
RF ACTIVITY DETECTED ?
252
NO
TO HUB ACTIVE STATE
YES
259
VALID FRAMES DETECTED ?
YES
NO
263
ADJUST CALIBRATION
265
NO
VALID FRAMES DETECTED ?
YES
261
WAIT TO RECEIVE INFO FRAME
258
TO REQUEST TXOP STATE

Fig_16



267
DETERMINE TIME OF TXOP. REQUEST INTERVAL
269
SEND TXOP REQUEST FRAME
275
WAIT FOR RANDOM NO. OF COMM. CYCLES
271
AWAIT REPLY DURING NEXT CYCLE
273
REPLY ?
NONE
HUB HANDOFF FRAME
TXOP GRANT FRAME
277
TXOP NO.≠0 ?
NO
YES
279
SEND HUB HANDOFF REPLY FRAME
250
TO LISTEN RF STATE
260
TO REMOTE ACTIVE STATE
252
TO HUB ACTIVE STATE

Fig_17

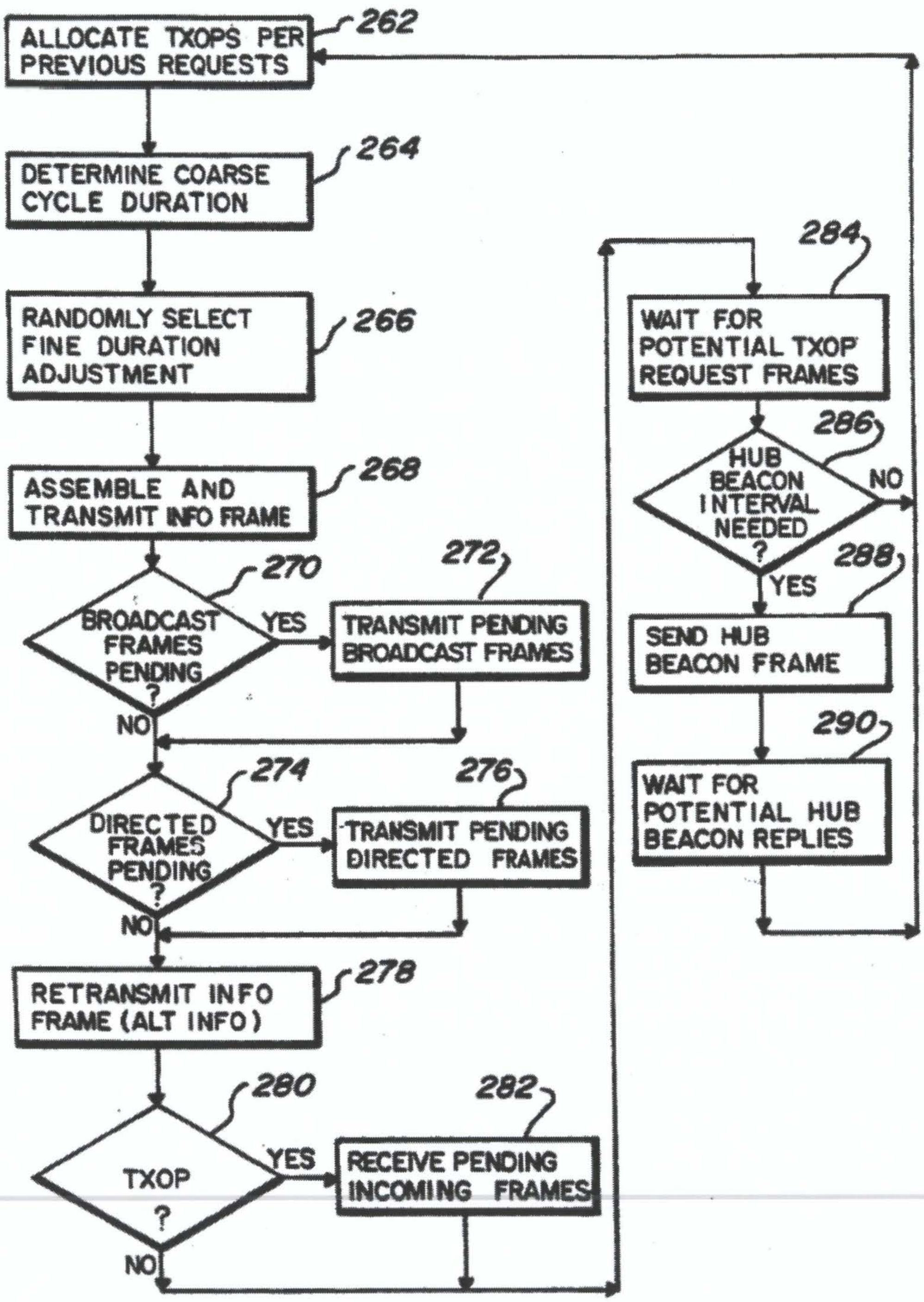
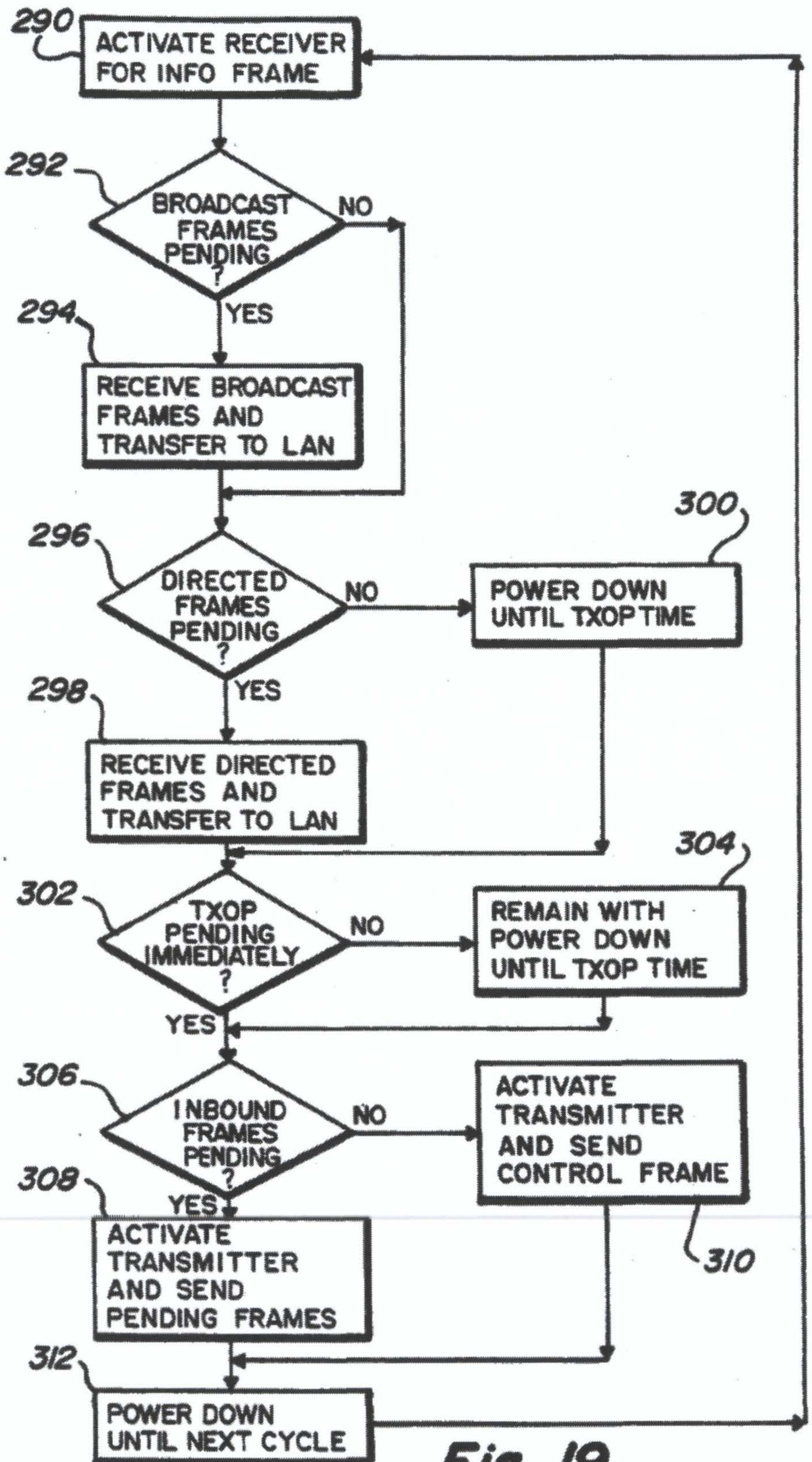

ALLOCATE TXOPS PER PREVIOUS REQUESTS
262
DETERMINE COARSE CYCLE DURATION
264
RANDOMLY SELECT FINE DURATION ADJUSTMENT
266
ASSEMBLE AND TRANSMIT INFO FRAME
268
BROADCAST FRAMES PENDING ?
270
YES
NO
TRANSMIT PENDING BROADCAST FRAMES
272
DIRECTED FRAMES PENDING ?
274
YES
NO
TRANSMIT PENDING DIRECTED FRAMES
276
RETRANSMIT INFO FRAME (ALT INFO)
278
TXOP ?
280
YES
NO
RECEIVE PENDING INCOMING FRAMES
282
WAIT FOR POTENTIAL TXOP REQUEST FRAMES
284
HUB BEACON INTERVAL NEEDED ?
286
NO
YES
SEND HUB BEACON FRAME
288
WAIT FOR POTENTIAL HUB BEACON REPLIES
290

Fig_18



290
ACTIVATE RECEIVER FOR INFO FRAME
292
BROADCAST FRAMES PENDING ?
NO
YES
294
RECEIVE BROADCAST FRAMES AND TRANSFER TO LAN
296
DIRECTED FRAMES PENDING ?
NO
300
POWER DOWN UNTIL TXOP TIME
YES
298
RECEIVE DIRECTED FRAMES AND TRANSFER TO LAN
302
TXOP PENDING IMMEDIATELY ?
NO
304
REMAIN WITH POWER DOWN UNTIL TXOP TIME
YES
306
INBOUND FRAMES PENDING ?
NO
ACTIVATE TRANSMITTER AND SEND CONTROL FRAME
310
YES
308
ACTIVATE TRANSMITTER AND SEND PENDING FRAMES
312
POWER DOWN UNTIL NEXT CYCLE

Fig_19

MEDIUM ACCESS CONTROL PROTOCOL FOR WIRELESS NETWORK

CROSS-REFERENCE TO RELATED APPLICATION

This invention relates to an invention for a Technique for Bridging Local Area Networks Having Non-Unique Node Addresses, Ser. No. 08/011,361, filed concurrently herewith, by the inventor hereof, and assigned to the assignee of this Application. The disclosure of this related invention is incorporated herein by this reference.

FIELD OF THE INVENTION

This invention relates to a technique and protocol for connecting multiple distinct computer resources by radio frequency (RF) or other wireless communications to establish a single logical network of the resources to permit communication between the distinct resources similar to that of a local area network (LAN). Even more specifically, the present invention relates to a medium access control (MAC) technique or protocol for selectively activating and deactivating the transmitters and receivers of the means for communicating between the resources to save electrical power consumed while still permitting LAN-like functionality, thereby extending considerably the ability of the resources to remain operable when battery powered.

BACKGROUND OF THE INVENTION

A LAN is a well-known means of achieving communication between different resources, typically computer resources such as computers, work stations, printers and the like. The LAN itself includes a network interface connected to each resource and a physical communication medium connecting all of the interfaces. The interface and connected resource constitute a node. Each node has an unambiguous address or identification (ID). Communication between nodes is typically accomplished by sending and receiving an ordered Group of bits known as a frame or packet. Each frame is sent from a source node, and is received by a destination node. The ID of the source node (SID) and the ID of the destination node (DID) are frequently included within the frame in Groups of sequential bits known as fields. The technique of communicating between the nodes, and of controlling the composition of frames, is defined by a network protocol.

The network protocol includes a MAC aspect which establishes an orderly and predictable ability of each node to access the medium, for the purposes of communicating with another node by transmitting and receiving frames, of requesting access to the medium and acknowledging previous frame communication. Without an orderly and predictable MAC technique, chaotic and inefficient communication, if any, would prevail, because it is highly unlikely that the frames sent from the source node would reach the destination node without interference and disruption caused by conflicting frames sent by another node at the same or overlapping time periods or at a time that the destination node was not ready to receive a frame. Therefore, the MAC facilities are one of the very important aspects of any LAN-like communication protocol among a plurality of equal peer-type transmitting and receiving stations such as nodes.

Because of the increasing recognition of the benefits of communicating information quickly between resources and of sharing resources in computational situations, LANs and networking in general are becoming widely used. Networking of personal computers and work stations allows for easy and effective communication and exchange of information between computers, as well as cost effective sharing of computer resources such as hard disks and printers.

Implementing a LAN can present a significant impediment when it is recognized that all of the resources must me wired together, particularly if the resources are physically separated and numerous. It is not unusual that many thousands or tens of thousands of feet or meters of cable may be required to connect a few tens or hundreds of resources, even when none of the resources is separated by more than a few hundreds of feet or meters. In existing facilities, sufficient physical access may not be available to route the necessary cabling. Installation, even if possible, may be very expensive. Even in designing and constructing new facilities, the cable expense itself for networking among a large number of personal computers or work stations may be cost-prohibitive.

Networks of LAN-like functionality have been established in the past by implementing the communication medium with wireless RF links between the resources. One difficulty presented by such systems is that MAC becomes considerably more difficult, because the RF links do not permit the transmitting and receiving stations (akin to nodes on a LAN) to sense the use of the medium (the RF signals) as reliably as in a wired network. Timing and synchronization requirements for the transmission of messages, static and interference from sources of RF noise, transmission and reception range limitations, multipath interference and fading and other known difficulties, all become significant concerns and limitations in implementing MAC protocols for wireless networks. These same concerns are generally not regarded as highly significant in wired or optical fiber networks because the integrity of the cabled medium usually avoids most if not all of these concerns. The integrity of the wired communication medium usually eliminates or significantly reduces the concerns about interference because the cabling offers inherent shielding from interference. Because the integrity of the communication is essentially assured in transmissions over the wires, range and signalling issues generally do not become significant. Light links have also been employed in networks, but the difficulties with light linked networks are usually even more exaggerated because of the directionality required for directing light beams in unobstructed, line-of-sight, signal paths.

To make the communications more reliable by avoiding many of the problems caused by the difficulties associated with the wireless medium, a variety of different MAC techniques have been employed in wireless network systems. In general the objective of these MAC techniques has been to add reliability to the communication process by compensating, to a certain degree, for the greater uncertainties associated with the wireless medium.

One of the most widely used MAC techniques, originally developed for wireless network systems, but now employed for several of the most common wired network standards, is referred to as carrier-sense multiple access (CSMA). In CSMA, each station uses its receiver to monitor the network medium for other transmission

activity prior to activating its transmitter. If any such activity is detected, the station waits until a predetermined time after the end of the detected network activity. If two or more stations begin transmitting at close enough to the same point in time so that none of these stations detect each other's transmission, the resulting transmissions are said to collide, with the result that none of the frames being transmitted by these stations are able to be successfully received at their intended destinations.

While CSMA protocols offer very low latency to begin communication during periods when little or no other network message traffic is active, they perform poorly when many stations are contending for access to the medium to send frames or when the aggregate amount to be transmitted exceeds about half of the data bandwidth of the network medium. In addition to this problem with saturation at well below the rated capacity of the network, wireless CSMA networks have increased chances for collisions when compared with wired CSMA networks, because obstructions to RF signal propagation could permit a station to erroneously detect an available network medium, allowing that station to activate its transmitter while another station was in the process of sending a frame.

Another MAC technique which is typically used in wireless networks is referred to as time division multiple access (TDMA). In TDMA, the available time for the multiplicity of the stations to access and use the radio links is divided among each of the stations. Each station has its own predesignated and assigned time Txop for communicating RF messages with other stations. Each station recognizes and operates under recognition of the order and sequence of the time Txops assigned to the other stations, to avoid overlap and conflict in the communications.

While TDMA protocols are generally very effective in providing reliably recognized opportunities for communicating messages, they can result in a reduced capacity or data bandwidth for transmitting information between stations when the communications are intermittent quantities of variable length messages ("bursts"). In burst message situations, which are highly typical of LAN-type communications, TDMA results in reduced useable data bandwidth because a large portion of the available time is unused for data communications because that time is assigned to stations that have nothing to send when their time slots occur. In situations where one station may have a considerable amount to send, the information must be broken up into parts and sent in sequence, one part each time the station's time occurs. Thus, TDMA, while providing reliable medium access in the difficult medium access environment of wireless networks, does not provide the higher message throughput or bandwidth as do some of the more traditional LANs.

Another MAC technique which is typically used in wireless networks is referred to as packet reservation multiple access (PRMA). In PRMA, each of the multiplicity of the stations must request and reserve a time to access and use the radio link to send its packets or frames. The requests are made on the basis of the amount of time that each station expects to use in communicating the amount of information it has queued for delivery to another station. The available time for all the stations to communicate is divided among each of the stations according to the requests of the stations. The time allocation reserved for each station is communicated to all of the stations, so all of the stations recognize which stations have a time allocation, how long the time allocation is and in what order the stations will receive and use their allocations. After this information is conveyed, each station requesting time uses its reserved time in its assigned order to communicate packets or frames with other stations.

PRMA techniques are more effective than TDMA techniques in utilizing the available time, because only those stations with messages to send need to be provided with an opportunity to send messages. However, fast response to requests is impossible because of the delays inherent in obtaining a reservation. A considerable amount of the available time is consumed in the rather complex communication of control information, referred to as "overhead." The overhead is used for requesting time, allocating a reservation of time, communicating the amount of time reserved, communicating the order in which the stations receive the time reservations, and the like. As a consequence, the quantity of useful data bandwidth of PRMA networks is also limited.

Another recent development in the field of computing is the increasing proliferation of battery-powered, portable computers. These portable computers allow computational tasks to be performed wherever the user happens to be located. Portable computers are usually used during travel, because portability is their primary advantage. Even during travel, however, there may be a need to access other computer resources through the portable computer, just as is more typically done with stationary resources. It may desirable to create temporary, ad hoc networks of portable computers so that, for example, users can network their portable computers to exchange data in meetings and classrooms. Of course in these situations, physically connecting the portable computers to a wired network medium may be inconvenient or impossible. In addition, the users and their locations may not be specifically predefined, and may change intermittently. In addition, to connect portable computers with RF or other wireless networking capability, it is necessary that the transmitters and receivers also operate from battery power, otherwise one of the primary benefits of wireless networking is negated by requiring the use of a power wire instead of a network medium wire. The additional power drain resulting from operating the transmitters and receivers diminishes the available power for the portable computer. If separate batteries are employed for the transmitter and receiver on one hand and for the portable computer on the other hand, the batteries for the transmitter and receiver should be able to provide as much longevity of use for the transmitter and receiver as the batteries for the portable computer provide, without being so large or heavy as to interfere with portability.

A major obstacle to adequate battery life for battery-operated wireless network interfaces is that conventional MAC protocols, whether using CSMA techniques, TDMA techniques, PRMA techniques, or other techniques (such as token passing), all assume that the network receivers are capable of receiving frames at all times that they are not actively transmitting. Consequently these MAC prior techniques are concerned only with controlling access to the network medium by transmitters. Because low-power, short-distance radio transceivers consume about as much electrical power in their receiving function as in their transmitting function, a useful protocol for battery operated networking must

avoid this assumption, and must concern itself with the access to the network medium by the receivers as well as the transmitters.

It is against this background that the significant improvements and advancements of the present invention have evolved.

SUMMARY OF THE INVENTION

It is the overall objective of the present invention to provide a reliable medium access control (MAC) protocol for wireless, preferably radio frequency (RF), LAN-type network communications among a plurality of resources, such a battery powered portable computers. The MAC protocol of the present invention provides the reliable, predictable aspects of medium access similar to those obtained in TDMA, and also provides the more effective allocation of available bandwidth among those resources which have messages to send, similar to those available from PRMA. In addition, the MAC protocol of the present invention avoids many of the disadvantages associated with the inefficiencies of LAN-type burst communications in TDMA, the high overhead requirements for communications in PRMA, and the problems of avoiding collisions and saturation that affect CSMA. Further still, the present invention provides a MAC protocol which may be very effectively implemented with communicator stations used with portable computers, because it obtains significant reductions in battery power drain by permitting the receivers as well as the transmitters of the communicator stations to be powered off during a majority of the time, but selectively and predictably powered on to send or receive relevant communications.

In accordance with these and other aspects, a communicator station or communicator wirelessly transmits frames to and receives frames from a least one additional communicator in accordance with a predetermined MAC protocol. Each communicator includes a transmitter and a receiver. The communication occurs among members of a Group of communicators. The MAC protocol controls each communicator of the Group. One of the communicators of the Group is designated as a "hub" and the remaining communicators are designated as "remotes". The hub establishes repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames. The hub transmits control information to the remotes to establish the communication cycle and to establish a plurality of predeterminable intervals during each communication cycle. These intervals allow the hub to transmit frames to the remotes, allow the remotes to transmit frames to the hub, and allow each remote to anticipate receiving frames from the hub. Due to the defined intervals of the communication cycle and the information conveyed by the hub, the remotes are able to power off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub. In addition, and very significantly, the remotes are able to power off their receivers during times other than those intervals when the remote is expected to receive frames from the hub. Thus, the control information and the communication cycle conserve considerable power because the receivers and transmitters of the remotes may remain powered off for a considerable portion of time without degrading communications.

Another desirable aspect of the MAC protocol of the present invention is that the hub allocates transmission opportunities (Txops) to the remotes, preferably based on bandwidth requests from the hubs. Txop allocation information is communicated to the remotes. Previous Txop allocations may be revoked or relinquished for non-use or very low use as determined by the hub monitoring the frames transmitted by each remote, for example. In addition the Txop allocations may be varied or adjusted by the hub from one communication cycle to the next to account for changes in activity of the remotes. The adjustment occurs in relation to the number of frames or quantity of data transmitted by each remote during recent communication cycles. Thus, the desirable aspects of TDMA are achieved by providing specific predeterminable intervals for Txops, and the desirable aspects of PRMA are achieved by adjusting the durations of the Txops to accommodate the communication of the more active remotes. Battery power concerns are addressed by allowing the predeterminable intervals for receiving frames, thus allowing the receivers to be powered off until the frames are anticipated.

Another aspect of the MAC protocol of the present invention involves conveying a variety of beneficial information concerning the communication cycle to the remotes, preferably at the beginning of each communication cycle, to achieve numerous other improvements. The hub transmits information to the remotes in a manner which does not incur a high overhead penalty. The hub preferably adjusts the length of a communication cycle relative to the length of a previous communication cycle to avoid some of the problems of interference from sources of periodic noise. The hub preferably transmits the information to the remotes twice during each communication cycle to reduce the possibility of a remote failing to receive the information during any communication cycle. Each remote preferably has the ability to select one among the plurality of antennas with which to receive RF signals during each communication cycle based on the strength of the received signal, preferably during a preamble portion of a transfer unit from the hub which includes the information. Preferably, the RF signals employ direct sequence spread spectrum modulation and demodulation established by a predetermined spreading code set by the hub to more effectively achieve good communication. The hub and a newly active remote also exchange operating characteristic information to allow negotiation of which communicator would better serve as a hub for the Group. The operational responsibility as the hub is preferably transferable from one communicator to another. Adjacent hubs of different Groups also communicate to adjust their operating characteristics and those of the remotes in their Groups to avoid conflicts in transmissions. The remotes also transmit transfer units that contain information describing the frames that were successfully received during a pervious communication cycle to allow retransmission of the frames unsuccessfully received without having to retransmit all of the frames. These are examples of a few of the many improvements available from the present invention.

A more complete appreciation of the present invention and its scope can be obtained from understanding the accompanying drawings, which are briefly summarized below, the following detailed description of a presently preferred embodiment of the invention, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a Group of wired LAN segments bridged together by RF communications between communicators connected to each LAN segment in accordance with the present invention.

FIG. 2 is a block diagram similar to FIG. 1 showing the relative RF transmission ranges of a hub communicator of the Group shown in FIG. 1, and some of the other remote communicators of the Group, shown in FIG. 1.

FIG. 3 is an illustration of a communication cycle established by the hub communicator shown in FIGS. 1 and 2 to control outbound signal transmissions from the hub communicator to the remote communicators of the Group and to control inbound signal transmissions from the remote communicators to the hub communicator of the Group.

FIG. 4 is a block diagram of a communicator shown in FIGS. 1 and 2.

FIG. 5 is a block diagram of a RF modem of the communicator shown in FIG. 4.

FIG. 6 is a diagram showing components of a transfer unit which is communicated between communicators as shown in FIG. 1.

FIG. 7 is an expanded diagram of a payload of the transfer unit shown in FIG. 6.

FIG. 8 is an expanded diagram of a frame which forms a portion of the payload shown in FIG. 7.

FIG. 9 is an expanded diagram of fields of a header of the frame shown in FIG. 8.

FIG. 10 is a diagram showing the intervals occurring during an outbound portion and an inbound portion of the communication cycle shown in FIG. 3.

FIG. 11 is an expanded diagram of a portion of FIG. 10, showing transfer units and frames transmitted during the outbound portion of the communication cycle.

FIG. 12 is an expanded diagram of a portion of FIG. 10, showing the transfer units and frames transmitted by the remote communicators during their allocated transmission opportunities (Txops) in the inbound interval of the communication cycle.

FIG. 13 is an expanded diagram of a transfer unit and a frame sent by a remote communicator to the hub communicator to obtain a Txop allocation in the communication cycle.

FIG. 14 is an expanded diagram of exemplary transfer units and frames sent by hub communicators of adjacent Groups during a hub beacon interval of the communication cycle.

FIG. 15 is an operational state diagram showing the operation of the communicators shown in FIG. 1.

FIG. 16 is a flow chart of the operations occurring during listen RF active state of operation shown in FIG. 15.

FIG. 17 is a flow chart of the operations occurring during a request Txop state of operation shown in FIG. 15.

FIG. 18 is a flow chart of the operations occurring during hub communicator active state of operation shown in FIG. 15.

FIG. 19 is a flow chart of the operations occurring during remote communicator active state of operation shown in FIG. 15.

DETAILED DESCRIPTION

A plurality of LAN segments which may be bridged in accordance with the present invention are shown in FIG. 1 and referenced at **30***a*, **30***b*, **30***c*, **30***d*, **30***e* and **30***f*. LAN segments generally will hereinafter be referred to by the reference number **30**, while specific LAN segments shown in FIG. 1 will be referenced by an alphabetical identification in conjunction with the reference numeral **30** as shown. Each LAN segment **30** is in actuality a LAN or at least one node of LAN. Each LAN segment **30** includes a physical communication medium **32** which connects nodes **34** of each LAN segment **30** in a network topology (bus, ring, star, etc.) which is illustrated as a bus in FIG. 1 for simplicity. The communication medium **32** will typically take the form of electrical connectors interconnecting the nodes **34**, but may also include radiant energy links, such as modulated light links, as are known to be employed in LANs.

Each node **34** comprises a network interface **36** connected to the communication medium **32**, and one or more resources **38** connected to the interface at each node **34**. The resource **38** can assume a variety of different configurations, as is known, but will typically include a computer such as a work station, portable computer, personal computer, printer, server, or the like.

Communication between separate nodes **34** and the resources **38** on those LAN segments **30** which have multiple nodes **34** and resources **38**, such as LAN segments **30***a*, **30***b* and **30***e*, is accomplished in accordance with a network protocol which governs the transmission and receipt of communications, known as LAN packets, over the medium **32** linking the interfaces of the nodes **34**. The communication actually is undertaken by the interfaces **36** transmitting and receiving the LAN packets over the communication medium **32** to establish communication between the nodes **34**. The form of the LAN packets is also controlled by the network protocol which governs the communications over the LAN segments **30**.

To allow orderly and reliable communication between the nodes **34**, each node **34** has its own node address or NID. The NID of each node **34** is maintained by the interface **36** associated with the node. As shown in FIG. 1, exemplary NIDs for each node are illustrated enclosed within circles within the rectangles designating each node **34**. The LAN packets transmitted from a source node typically contain the address of the source node (SID) sending the packet, and the address of the destination node (DID) to which the packet is addressed, in accordance with the typical network protocol.

Some of the LAN segments, i.e. **30***c*, **30***d* and **30***f*, are single resource, single node LAN segments. Thus, it is impossible to communicate between nodes on those LAN segments because two active nodes, a source node and a destination node, are required for LAN packet communication, and two nodes do not exist on those LAN segments. The other LAN segments, i.e. **30***a*, **30***b* and **30***e*, permit LAN functionality between the nodes **34**, because each LAN segment contains at least two nodes **34**. The preferred embodiment uses the RF MAC protocol for bridging between LAN segments, however the MAC protocol of the present invention is for communication between RF nodes. In alternate embodiments, the communicator function **60** can also be used directly as a LAN adapter, replacing the interfaces **36** of the PC or other resources **38**.

One capability of the present invention is to bridge together the LAN segments **30**, whether single node LAN segments (**30***b*, **30***c* and **30***f*) or multiple node LAN segments (**30***a*, **30***b* and **30***e*) so that all of the

nodes **34**, regardless of the type of LAN segment **30** upon which they appear, can achieve effective LAN like communication among a "Group" of separate LAN segments. The number of LAN segments which can be bridged is preferably limited to a predetermined number, for example sixteen. The communications between the LAN segments will be transparent to the network interfaces **36** and without altering the protocol used on any of the LAN segments **30**. In essence, the bridged LAN segments **30** establish a single logical LAN.

To bridge the LAN segments **30** together for effective communication between the nodes **34**, communicator stations or communicators **60a**, **60b**, **60c**, **60d**, **60e** and **60f** are connected to each LAN segment **30a**, **30b**, **30c**, **30d**, **30e** and **30f**, respectively, as is shown in FIG. **1**. Each communicator will hereinafter be generally referred to by the reference number **60**, while specific communicators shown in FIG. **1** will be referenced by an alphabetical identification in conjunction with the referenced numeral **60** as shown.

Another more general capability of the present invention is to serve as a self-contained, wireless network or LAN, with the communicators attached directly to the resources **38**, in place of the wired LAN segments **32** and the associated interfaces **36**. In this more general usage, the communicators directly connect to a resource and convey LAN packets or other information using the MAC protocol of the present invention, and no bridging between separate LAN segments occurs. It should be understood that the MAC protocol of the present invention is equally applicable to either situation.

Each communicator **60** communicates with the node or nodes **34** on the LAN segment **30** (or resource **38**) to which it is locally attached. A "local" node or a "local" LAN segment or resource is the one which is directly connected by the communication medium **32** to the communicator **60** with regard to which the reference "local" is made.

Each communicator **60** preferably includes a LAN interface **36**. The interfaces **36** in the nodes **34** and in the communicator **60** are the same, and they operate in accordance with the same network protocol. Communications over the local LAN segment between communicator **60** and each node **34** occur through the interfaces **36** and the communication medium **32** in accordance with the network protocol, just the same as communications between two nodes **34** on a local LAN segment. Because the interfaces **36** associated with the communicators **60** communicate with the interfaces **36** associated with the nodes **34** under the same protocol, the interfaces **36** associated with the communicators **60** must have an NID like the other LAN interfaces **36**. However, the communicators **60** are not nodes **34**, as that term is used to describe LAN functionality, because the communicator **60** achieves the administrative functions associated with bridging instead of the usual information processing functions associated with a resource **38**. In the embodiment wherein the communicators **60** attach directly to the resources **38**, the communicators **60** do function as nodes on the wireless network, and this RF network serves as the LAN, so there are not separate LAN interfaces **36** nor LAN NIDs.

To bridge the LAN segments **30**, the communicators **60** transmit and receive radio frequency (RF) signals known as "frames." The communicator **60** which sends a frame is referred to as a transmitter communicator or "transmitter," and the communicator **60** (or communicators in the case of broadcast or multicast frames) which receives the frame is a receiver communicator or "receiver." Each frame is formed by a digital bit stream containing information and/or data to accomplish the bridging functions, the LAN functions and/or the MAC protocol aspects of the present invention described below.

The number of communicators in the Group may depend on their radio transmission range. The range may be limited due to government regulations limiting the amount of the power of the transmitted RF signal, by obstacles and obstructions which may block or attenuate the RF signals, and/or by interference from other, nearby transmitters, for example. Accordingly, all of the communicators may be unable to establish direct RF communications with one another. For example, in the arrangement shown in FIG. **2**, the communicator **60a** is not within the transmission range of the communicator **60d**, since the transmission range of the communicators **60a** and **60d** are represented by the circles **62a** and **62d**, respectively. Each communicator's transmission range will hereinafter be generally referred to by the reference number **62**, while specific communicator transmission ranges shown in FIG. **2** will be referenced by an alphabetical identification in conjunction with the referenced numeral **62** as shown. Therefore, direct communications between the communicators **60a** and **60d** are not possible. However, under the MAC protocol technique of the present invention, all of the communicators of the Group need not be within range of every communicator in the Group in order to obtain effective communication.

In order to expand the transmission area beyond the transmission range of any particular communicator **60**, one of the communicators **60** will function as a hub communicator or "hub" **64**. The hub **64** will act as a central receiver for the communications transmitted among the other communicators **60** of the Group. The communicators **60** other than the hub **64** are designated as remote communicators or "remotes" **66**. In addition to functioning as central receiver, the hub **64** also functions as a central relay station for relaying transmissions between the remote communicators **66** and for receiving messages from the remotes **66**. As shown in FIG. **2**, because both communicators **60c** and **60f** are within range of all the other communicators **60a**, **60b**, **60d** and **60e**, either would be a suitable choice for the hub **64** from the standpoint of communications range. However, in the situation where more than one communicator might adequately serve as a hub from the standpoint of transmission range, other factors (described below) determine allocation of hub status. In the example shown in Fib. **2**, communicator **60f** has been designated as the hub **64**.

Thus, because of its central location, the hub **64** will be able to receive and relay transmissions from all the communicators **60a**, **60b**, **60c**, **60d** and **60e** achieving communications between all communicators **60**, including those which are not within range of each other for point-to-point or direct communications, such as communicators **60a** and **60d**. In receiving and relaying all transmission in the Group of communicators **60**, the hub **64** allows for the single logical network to be larger than the transmission range **62** of a single communicator **60**. The remotes **66** need not be within transmission range **62** of each other to communicate as long as the remotes **66** are within transmission range of the hub **64**.

As shown in FIG. 2, the single logical network formed by the hub **64** and the remotes **66** represents a topology which is both a logical and a physical star. The physical star is found by the remotes **66** arranged around the more central hub **64**, which permits the single logical network of a physical size greater than the transmission range of any one of the communicators in the Group. The logical star results from the individual communication paths between the hub and each of the remotes. Signals are transmitted from the hub to all of the remotes, and from each of the remotes to the hub. The logical communication path for all of the transmissions is to or through the hub, thereby establishing the star topology. The physical layer of the seven layer ISO reference model for data communications is represented by this logical and physical star topology. All physical layer communications are either bilateral transmissions between a remote **66** and a hub **64**, bilateral transmissions between a hub **64** and a remote **66**, or broadcast transmissions from the hub **64** to all remotes **66**.

The operation of the communicators emulates the characteristics of a logical bus as viewed from above the link layer of the media access control (MAC) sublayer of the link layer of the seven layer ISO reference model for data communications. However, the physical and MAC layer functions are implemented using the star topology.

To achieve the MAC sublayer functionality, the hub **64** controls the communications to and from the remotes, using a MAC protocol according to the present invention. The foundation for this MAC protocol is allocation of media access for transmission (e.g. the right to energize the RF transmitters at the respective communicators) at appropriate, non-overlapping times and media access for reception (e.g. the need to energize the RF receivers at respective communicators), at appropriate times that RF frames may need to be received. These times, referred to as transmission opportunities (Txops), are controlled in the context of a communication cycle **70**, shown in FIG. **3**, which the hub establishes and which is repeated on a continuous basis as long as the hub is active. In contrast to conventional MAC protocols, the present invention is concerned with media access for reception as well as for transmission. The hub governs the sequence of its own frames which are contained in transfer units, transmitted outbound from the hub **64** to the remotes **66** during an outbound portion **72** of the communication cycle **70**. The hub also controls the sequence and duration of frames which are contained in transfer units which are transmitted inbound from the remotes **66** to the hub **64** during an inbound portion **74** of the communication cycle. It is during the outbound portion **72** and inbound portion **74** of the communication cycle **70** that all frames are communicated.

During the outbound portion **72** of the communication cycle, as shown in FIG. **3**, there is an initial information (info) interval **76** during which the hub **64** transmits control and other information to the remotes **66**. This information allows each of the remotes **66** to recognize and participate in the communication cycle at the predetermined times. A broadcast interval **78** is also included in the outbound portion **72** to allow the hub **64** to broadcast the same information to all of the remotes **66** in the Group, using a single transmission that is expected to be received simultaneously by all remotes **66**. A directed packet interval **80** is also provided to allow the hub **64** to transmit frames to specifically identified remotes **66** in the Group. Because of the importance of the information communicated during the initial information interval **76**, the information communicated in the initial information interval **76** is repeated in an alternative information (alt info) interval **82**. By repeating the transmission of the control information in the alternative information interval **82**, the chance for the remotes **66** to lose the synchronized nature of operation with the hub **64** is substantially diminished. In addition, during the information intervals **76** and **82**, frames previously transmitted from the remotes to the hub during the inbound portion of previous communication cycle are acknowledged by the hub.

During the inbound portion **74** of the communication cycle **70**, those remotes **66** which have requested a transmission opportunity (Txop) to transmit messages to the hub **64** are provided with an opportunity to do so. Generally, the hub **64** allocates to each remote **66** requesting one a Txop **84**. The Txop **84**, simply is a position in the order of other remotes **66** which have requested Txops **84** to transmit to the hub **64**. The Txop is an amount of time during which the remote may transmit one or more frames to the hub. The Txops **84** are preferably allocated to the remotes **66** by the hub **64** in a predetermined order, and the hub may also vary the time durations of the allocated Txops **84**, without varying their order. All remotes receive a Txop **84** with (at least) a predefined minimum duration on each communication cycle **70**, whether or not they have any frames to transmit. The hub may adjust the duration of the Txops **86** by observing traffic patterns and in accordance with information received from each remote **66** relating to the amount of information which each remote has queued for transmission, among other factors. Besides using the allocated Txop to transmit frames from a remote **66** to the hub **64**, the remote also acknowledges any directed frames communicated to it from the hub **64** during the communication cycle. If there is one or more outgoing frame, the remote **66** may "piggyback" these acknowledgements with these outgoing frames. In addition, if the Txop **84** is not used by the remote **66** for a predefined number of communication cycles **74**, the hub **64** may determine that it is not necessary to preserve a Txop for a particular remote **66**, and thereafter cancel the Txop **84** allotted to that remote **66**.

After the series of Txops **84** are allocated, a Txop request interval **88** is provided. During the Txop request interval, communicators **60** which have recently joined the Group, or communicators **60** which have not previously been allocated Txops **84** in which to transmit messages are allowed to transmit messages to the hub **64** requesting that they be allocated a Txop. Upon receipt of the Txop request, the hub **64** will allocate a Txop **84**, if any are available. The hub **64** will inform the requesting remote (and all other remotes) of this Txop allocation in the information intervals **76** and **82** of the next communication cycle. This dynamic allocation of Txops **84** is particularly beneficial in situations where portable communicators move into and out of range of the Group's hub at arbitrary times, and should neither burden the available aggregate bandwidth of the Group with an unused Txop when it is not present nor require user intervention when it rejoins the Group.

Thus the communication cycle **70** orders the transmission of communication control information to the remotes **66** (including acknowledgements to previous frames received from the remotes **66**), allocates inbound

Txops **84** in accordance with the amounts of transmission time requested by each remote (and other factors), transmits outbound frames (both broadcast and directed) to the remotes **66**, and receives inbound frames from the remotes **66** pursuant to the previously-made Txop allocations. The remotes **66**, in their allocated sequence of Txops **84**, acknowledge previous frames received from the hub **64**, and transmit inbound frames to the hub **64**. In addition the remotes may request allocation of Txops when needed during the Txop request interval **86** of the inbound portion **74**.

All intervals of the communication cycle **70** take place within the limits of predesignated assigned times established by the hub. Each interval is measured in terms of a number of basic time increments (BTIs) prespecified to all communicators in the Group. A BTI is a predefined unit of time (parameterized, default of 4 milliseconds, for example) that is the fundamental increment of communication cycle **70** time allocation, and is the metric by which intervals within the communication cycle **70** are measured. The hub **64** controls the duration and usage of the communication cycles **70**. The time for the overall communication cycle **70**, along with the specific interval allocations within the cycle **70**, are broadcast by the hub **64** in during the information intervals **76** and **82** in the form of control information delivered in an information frame transmitted during the information interval **76**.

Because all frames, both outbound and inbound, occur at predetermined times, the remotes **66** are able to determine in advance approximately when to expect frames transmitted from the hub and when to transmit frames to the hub. As a consequence of the predictable times when frames may be both received and transmitted, the remotes can power their radio interfaces down to preserve power at other times. Because radio circuits with radiated RF energy levels that comply with the rules in Part **15** of the FCC regulations consume about as much electrical power when receiving as when transmitting, this ability to power the radio off completely is a major benefit for battery-powered communicators. This MAC protocol control feature is of particular importance in facilitating portable computer attachment. When the remote battery-powered communicators are used, as would typically be the case when a personal, portable computer is the resource attached, this power down capability makes it possible to obtain an increase in useful battery life of over five times compared to the battery life if the radio interface was continuously powered for reception (or transmission).

The communication cycle features of the MAC protocol also provides efficient, low-latency support for typical LAN usage patterns, in which frame size distribution is strongly bimodal (one mode quite short, the other mode at or near the maximum frame size for that LAN protocol), and frame arrival rates are burst like (highly non-uniform, with shifting peak traffic locations). Only those communicators which transfer frames on a regular basis are regularly allocated Txops longer than one BTI, thereby reserving bandwidth for those more active remotes. In addition the relative allocation of the time among the remotes favors those which have requested and used more time for frame transmissions in the recent past, which again keeps with the shifting peak traffic patterns of LAN-like communications.

By controlling Txops in a timed sequence, the hub **64** serves a number of purposes, including: media access control, with specific Txops allocated to specific remotes; bandwidth allocation, in response to requests that indicate the amount of data awaiting transmission, thereby permitting adaptive allocations that favor the (dynamically changing) remotes **60** that have the most pending traffic; power management, as described; basic security, since each communicator **60** must be allocated a Txop before being able to participate in frame exchanges; MAC-layer frame acknowledgement (without a power consumption penalty), because acknowledgements can be piggybacked on subsequent frames with a known upper bound on the time delay from the original transmission attempt; and network administration, because all frames traverse the Group's hub **64**.

Specific details concerning the communicators **60**, the frames transmitted and received, the communication cycles and the functionality of the communicators in achieving the MAC protocol functionality of the present invention are described in greater detail below.

Details of the communicator **60** are shown in FIGS. **4** and **5**. The communicator **60** combines radio hardware, interface hardware, and the necessary firmware to implement a transparent, wireless logical network between the communicators **60**. The communicators preferably transmit and receive messages over a wireless physical layer provided by a direct-sequence, spread spectrum (DSSS) radio data link. A half-duplex, packet-oriented transfer medium is thereby established with sufficiently high data rate, sufficiently short transmit/receive turnaround time, sufficiently low power consumption and transceiver on/off speed, sufficiently low framing overhead requirements, and sufficiently high data reliability to support LAN-like operational characteristics between the separated LAN segments. Other packet-oriented, wireless data links that have adequate operational speed and related characteristics can be substituted for this DSSS radio link without changing the MAC protocol of the present invention. The communicator **60** also supports directly the logical-link control sublayer, network layer and all higher layers of communication, rendering the location-sensitive aspects of the wireless data link transparent to the attached resources. Each communicator **60** is not a node on the local LAN segment, but is a node on the wireless network.

The general nature of a communicator **60** is shown in FIG. **4**. Each communicator **60** has a network interface **36**, a microcontroller **90**, a read only memory (ROM) **92**, a random access memory (RAM) **94**, and a RF modem **96**, all of which are interconnected by a bus **98**. The interface **36** is equivalent to that used by each node **34** on the LAN segments **30**. The attachment of the interface **36** to the bus **98** and the microcontroller **90** is similar to that manner in which the interface **36** of a node **34** connects to its attached resource **38**. The microcontroller **90**, in its presently preferred form, is a Motorola 68HC16 microprocessor. The instructions controlling the operation of the microcontroller are stored as firmware in the ROM **92** and/or in software instructions in the RAM **94**. These instructions implement the MAC protocol described herein. The RAM **94** contains a buffer to temporarily store information used when the communicator **60** is functioning. The information stored in the RAM **94** may be copies of LAN packets received from the interface **36** and awaiting transmission on the RF network, copies of frames received from the RF modem **96** and awaiting transmission on the LAN segment **30**, or (for hub communicators) cop-

ies of frames received from one remote and addressed to another remote, awaiting transmission in an outbound interval of the communication cycle.

RF signals are transmitted to and received by the communicators at the RF modem **96**. The RF modem **96** preferably has at least two antennas **100** and **102**. The antennas are oriented in different configurations, to allow selection of the one which provides the best reception. Transmission of the signals usually does not require antenna selection, because signal transmission usually does not involve as many sensitive aspects as signal reception. At any physical location of a communicator, one of these antennas **100** or **102** is likely to offer better signal reception than the other. Selection of the best antenna is performed by software instructions in the RAM **94** as part of the signal acquisition process which the communicator **60** undertakes in conjunction with the receipt of RF frames. The time required to determine that the signal reception from one antenna is inadequate, and then to synchronize to the signal being received by the other antenna, is time during which transmissions cannot be successfully received by a communicator **60**. Accordingly, the MAC protocol implementation involved in communicating the RF frames and the low-level radio control functionality in the microcontroller **90** cooperate to permit the selection of a better antenna.

The RF modem **96** accepts a digital data stream from the bus **98** at the transmitting communicator **60**, produces and transmits the RF signal, and the RF modem **96** at the receiving communicator **60** receives the RF signal and produces a digital data stream corresponding to that supplied to the transmitting RF modem **96** (other than in the presence of errors due to RF interference or excessive RF signal attenuation). The transmitting and receiving RF modems **96** perform all of the necessary spreading, modulation, demodulation, and despreading functions to successfully transfer the frames between communicators. The transmitting RF modem **96** also generates a preamble at the beginning of each transfer unit (of one or more frames) that allows the receiving RF modem **96** to acquire and synchronize with the transmitted radio signal. However, all other data communication functions, including framing, formatting, address recognition, error detection, and link control, are imposed upon the physical layer digital data stream by the present invention at the MAC layer by non-RF modem hardware and microcontroller-based firmware of each communicator **60**. At this MAC layer there is also a close interaction with the RF modem to achieve various control and calibration functions, including power consumption control, oscillator calibration and temperature compensation, receiver automatic gain control calibration, received signal acquisition, antenna selection for spatial diversity at the receiver; and transmitter power control (adaptive power management) associated with each communicator **60**. Some of the calibration parameters provided by the RF modem **96** may also be used by the present invention for MAC layer control purposes, as well as by the RF modem **96** itself. In the preferred embodiment, the microcontroller **90** is also involved in processing the calibration parameters to calculate calibration responses to provide feedback to the radio.

The RF modem **96** in the preferred embodiment is a Model 100 DSSS RF Modem sold by Signal Technologies, Inc. of Longwood, Fla. The spread spectrum product operates a 191,176 baud, with a chip rate of 3.25 MHz at 17 chips per baud. The RF modem **96** is preferably programmed to operate on any or all four, non-overlapping frequency channels within the 902 to 928 MHz ISM frequency band defined by FCC rules. This RF modem **96** can support either binary phase-shift keying (BPSK), which achieves 1 bit/baud (for a data rate of 191 Kbps); or quadrature phase-shift keying (QPSK), which achieves 2 bits/baud (for a data rate of 382 Kbps). The BPSK functionally is identical to the QPSK functionality, other than for the data rate (half as fast), and synchronization time. The digital interfacing functions (spreading codes, etc.) and frequency synthesizer interfacing functions (frequency channels) are programmed in an identical manner for both BPSK and QPSK operation. One additional major difference concerns the calibration details, which must usually be separately established for each type of operation but in a manner that is independent of the MAC protocol that is the subject of the present invention.

The general nature of the RF modem **96** is shown in FIG. **5**. The RF signals are transmitted from or received by antennas **100** and **102**. A switch **103**, controlled by the microcontroller **90**, selects one of the (two or more) available antennas. The transmitted and received signals pass through a conventional RF filter **104**. A selection switch **106** controls the signal path through the filter **104** and antennas **100** and **102**. In one switch position illustrated in FIG. **5**, signals are received. In the other switch position, the signals are transmitted. Preferably, the switch is a gallium arsenide field effect transistor (FET) switch. When not transmitting, the selection switch **106** is set to accept incoming signals.

With the selection switch **106** in the receive position, the received signals pass through the filter **104** and are applied to a low noise amplifier **108**. The low noise amplifier **108** amplifies the signals and supplies them to another filter **110**. The signals from the filter **110** are applied to a radio device **112** which performs both a radio receiving function as well as an amplifying function. Signals from the radio device **112** are applied to a coherent demodulator **114**.

The coherent demodulator **114** extracts the base band data from the RF carrier signal which has been BPSK or QPSK modulated. The coherent demodulator **114** also functions as a coherent correlator for the spread spectrum sequence which modulates the data. A control signal for the coherent correlation or spread spectrum sequencing function is obtained from a spread spectrum controller **116**. The coherent demodulator **114** includes a base band automatic gain circuit (AGC) which keeps the signal levels predictable when the AGC signal is applied to the radio device **112**. The AGC circuit also forms part of a delay locked loop which interacts with the spread spectrum controller **116** during demodulation. A band gap reference signal is also supplied by the coherent demodulator **114** for use by other components. Since many of the signals in the coherent demodulator **114** are analog signals, the coherent demodulator **114** includes comparators to establish digital waveforms and provide in-phase and quadrature phase data outputs in a form compatible with the other digital components of the communicator. The coherent demodulator responds to the magnitudes of the in-phase, base-band and quadrature phase components of the received signal to establish a received signal strength indication (RSSI) signal representing the energy of the received demodulated signal. These signals are applied to the other compo-

nents of the RF modem **96** to assist in achieving the functionality of those components.

In general, the functionality of the coherent demodulator **114** is conventional and appreciated by a person having skill in the field of signal communications. For convenience, all of these functions are readily available on a single commercial integrated circuit designated as CSL-100 available from Signal Technologies, Inc. of Longwood, Fla.

One of the important features of the spread spectrum controller **116**, which results in beneficial message communication, is the ability to rapidly acquire and synchronize with incoming received signals. The shorter the time to acquire and synchronize adequately for correct demodulation, the smaller the portion of the frames that need be devoted to transmitting preamble signals necessary for synchronization, resulting in lower communication overhead and greater network efficiency. The ability of the spread spectrum controller **116** to quickly acquire and synchronize with received signals, may be advantageously achieved by employing the techniques described in U.S. Pat. No. 4,649,549. In the preferred embodiment, the spread spectrum controller **116** is a commercially available integrated circuit, having a designation AS-100, available from Signal Technologies, Inc. of Longwood, Fla.

In general, the components of the spread spectrum controller **116** include a timing distributor **118** which responds to a signal from an external clock oscillator **120** and distributes clock timing signals throughout the sections of the spread spectrum controller **116**. One of the major sections of the spread spectrum controller **116** is an interface **122**, which allows the exchange of control and data signals over the communicator bus **98** with the other components of the communicator **60**. Internal program registers **124** allow settings to be recorded therein through the interface **122** to configure the functionality of the spread spectrum controller **116** in many respects, for example to establish the polynomial sequence used in spreading and despreading the signals, controlling certain other elements in the RF modem **96**, selecting the type of modulation, maintenance functions and the like.

The interface **122** is connected to an internal bus **126**, and most of other components of the controller **116** are also connected to the internal bus. A transmitter/-receiver (Tx/Rx) power control **128** controls a number of elements within the RF modem **96** so that they can be properly power managed by selectively powering them down to save battery power, for example, if the communicator **60** is powered from a battery.

A spread spectrum generator and encoder **131** is a programmable device that allows for the implementation of a Galois polynomial sequence generator. An in phase, I-transversal filter **132** and a quadrature phase Q-transversal filter **134** receive signals from the spread spectrum generator and encoder **131** prior to RF modulation for transmission. For reception, a spread spectrum correlator and decoder **130** handles the demodulator **114** output to regenerate the unspread data. A baud synchronizer **136** allows a signal to be obtained which references to the data clock of the received data. The spread spectrum correlator and decoder **130** preferably employs the technology described in U.S. Pat. No. 4,649,549. A synthesizer interface **138** delivers signals to an RF synthesizer **140** which generates the various signals applied to the radio device **112** to down convert signals from the RF band and to up convert signals from the communicator **60** and spread spectrum controller **116**, in the case of received signals or transmitted signals, respectively.

The spread spectrum controller **116** accepts data through the interface **122**, translates the data from parallel to serial four and applies the appropriate spreading sequence to the data so that it becomes a base band spread spectrum signal. This information in spread spectrum form is applied to the radio transmitter **142** where it is converted to the appropriate RF band. The radio transmitter **142** applies the RF signal through the selection switch **106** and the filter **104** to the selected one of the antennas **100** and **102** where it is transmitted.

The communicators **60** dynamically perform frequency channel selection upon initialization, with the objective of minimizing interference between Groups that have overlapping RF communication spaces. If Groups are assembled using multiple hubs **64** which support inter-hub handoffs, the frequency channels may be statically assigned to each hub in order to provide repeatable handoff performance.

The present invention can be extended to provide wireless network communication for a wider physical area by providing a plurality of communicators predesignated as hubs all configured as part of the same Group and able to communicate with each other via a common (preferably high speed) wired "backbone" network. In the presence of such a multi-hub Group, a portable communicator that leaves the transmission space **62** of one hub of the Group, but entered the transmission space **62** of an adjacent hub in the Group (generally operating on a different frequency channel to avoid interference at the region of overlap) will detect the second hub during the attempt to detect an active hub after losing contact with the first hub. If this other hub is detected, by virtue of its being part of the same Group, and sharing a common backbone network over which the plurality of hubs can exchange LAN packets, the remote can remain in communication as part of the same logical network as soon as that remote has obtained a Txop allocation from the second hub. This type of microcellular functionality can be implemented upon the remote communicators attempting to re-establish communication with a hub (termed "passive handoff" because the hubs do not play an active role in the process) or by negotiation between the adjacent hubs when the RSSI level drops below a predetermined threshold (termed "negotiated handoff" because the hubs initiate the process of checking the relative signal strengths and determine the best destination hub for the handoff).

In the case of RF communication overlap between hubs **64** of different Groups that must operate on the same frequency channel, a technique must be employed to permit such hubs **64** to share the available RF bandwidth in an orderly manner, as is discussed below.

In applying the spreading sequence to the data, the RF modems **96** can be programmed to use any one of a large number of spreading sequences (for example several thousand spreading sequences), each of which is referred to as a code. All members of a Group of communicators **60** must be programmed to use the same code in order to achieve successful communication. Communicators **60** operating in the same RF communication space, and using the same frequency channel but a different spreading code than the Group members, cannot receive transmissions from other communicators of the Group, and transmissions by such other communicators may interfere with RF communication among

the Group members. The potential for such interference can be reduced, but cannot be eliminated, by selection of spreading codes with adequate Hamming distance from each other. Accordingly, a limited subset of the available code space, for example 1000–4100 codes, selected based on appropriate Hamming distances, will be used to minimize the risk of inter-Group interference and to maximize the degree of communication security provided by the spreading.

The spreading sequence codes form the basis for a level of communications security because unless a communicator **60** is utilizing the appropriate code, it cannot participate in the communications. Certain codes may be also reserved for special network control and diagnostic purposes. The code usage is identified by code identification numbers that are used to index tables within the communicator ROM **92** or RAM **94** that contain the specific multi-byte sequences needed to program the RF modem to generate these codes.

The potential for interference between adjacent Groups is further reduced if each transmission by a communicator **60** uses the minimum level of RF energy required to achieve the needed signal strength at the designated receiving communicator **60**. Reducing transmitted power may also improve the battery life of battery-powered communicators **60** by possibly consuming less power during typical transmissions. The ability to measure the received signal strength (RSS) at each end of a communication activity, plus the inclusion of a received signal strength indication (RSSI) parameter in certain frames communicated permits this type of adaptive management of transmitted power. Subsequent transmissions to a communicator that has reported excessively high RSSI values can be made using reduced transmit power. If RSSI levels are later reported to have dropped below a predetermined threshold, transmit power can be increased to compensate.

The digital data streams provided to the sending RF modem **96** are included in transfer units **144**, one of which is illustrated in FIG. **6**. The transfer unit **144** includes three components: a preamble **146**, a payload **148** and a postamble **150**.

The preamble **146** is a predetermined sequence of binary values which are used by receiving communicators **60** to acquire and synchronize to the incoming transmission. The preamble **146** provides the necessary amount of time with known information content for the demodulation and despreading functions of the RF modem **96** to acquire and synchronize with the signal prior to the beginning of the payload **148**. In the preferred embodiment, the preamble **146** consists of a sequence of alternating ones and zeros lasting at least 1 millisecond.

The length of the preamble **146** may be defined separately for various types of transfer units **144**. For transfer units **144** containing information frames, which are vital to maintaining the integrity of communications, a longer preamble **146** is generally used to provide a greater probability of acquiring the incoming signal, and to allow switching to the alternate antenna with enough preamble remaining to acquire and synchronize via the alternate antenna if RSSI levels through the first antenna prove insufficient. In addition, the preamble **146** for transfer units containing control information and hub beacon frames sent during the communication cycle is also generally longer than the minimum requirement to permit an alternate antenna to be selected midway through reception of the preamble **146** and still allow time for the RF modem **96** to synchronize to the signal using the alternate antenna. For transfer units **144** containing only normal data packet or bridge frames, a shorter preamble **146** is used because an error in a data packet frame will not impact communications to the same extent as an error in a control or information frame, and the use of longer preambles on such transfer units would increase network overhead. In the preferred embodiment, the default values for the length of the preamble **146** are 192 bytes for transfer units **144** containing information frames, 96 bytes for transfer units containing control frames, and 48 bytes for transfer units **144** containing neither control nor information frames. The preamble **146** is generated by the RF modem **96** of the transmitting communicator **60**, is used by the RF modem **96** of the receiving communicator for signal acquisition and synchronization, and is detected and discarded by the microcontroller and its related circuitry of the receiving communicator **60**.

The postamble **150** marks the end of the transfer unit **144**, and provides time (with RF signal activity) following transmission of the payload **148** that may be needed for the receiving communicator to complete successful reception of the payload **148** prior to cessation of RF signal activity. The postamble **150** also provides a period of non-communication of sufficient duration to prevent destructive interference from overlap between transfer units **144** transmitted by different communicators. This non-communication period compensates for the allowable degree of timekeeping uncertainty that can accumulate between communicators **60** in the Group during any communication cycle **70**. The postamble **150** is generated by firmware in the microcontroller **90** of the communicator **60**, and its length is a predetermined constant to ensure a minimum separation between transfer units **144**.

The payload **148** of the transfer unit **144** carries the substance of the communication. No restrictions are imposed by any of the components of the RF modems **96** on the contents or format of the payload **148**. The payload **148** of each transfer unit, which is shown in FIG. **7**, is a sequence of one or more frames. Frames are the fundamental data transfer entity of the present invention. Each transfer unit comprises one or more frames **152** separated by inter-frame gaps **154**. The frames **152** contain the substantive information transmitted in the transfer unit. The number of frames in any transfer unit is limited by the lesser of the amount of information to be sent by the communicator **60**, or for inbound communications from remotes **66** to the hub **64**, the maximum amount of time allocated to the remote by the hub **64** for use as a Txop in the current communication cycle. If the allocated Txop is insufficient to send all queued, outgoing frames, some number of complete frames will remain unsent at the remote until another Txop occurs in a subsequent communication cycle **70**. Frames **152** are never split up in different transfer units.

When multiple frames **152** are sent in a single transfer unit, these frames **152** are sent in direct succession, separated by inter-frame gaps (IFG) **154**. The IFG **154** provides a sufficient amount of time for the receiving communicator **60** to complete handling of the preceding frame **152** and to prepare for receipt of the following frame **152**. Each transfer unit thus contains an integral number of frames **152** and an integral number of IFGs **154** which is equal to one less than the number of frames **152**. The IFG **154** is generated by the microcontroller

90 of the transmitting communicator 60 and is discarded by the microcontroller 90 of the receiving communicator 60.

Each frame 152 has the same basic format, one of which is shown in FIG. 8. Each frame is formed by five fields: a starting flag 160, a header 162, a body 164, an ending flag 166, and a cyclic redundancy check (CRC) 168.

The starting flag 160 is a unique bit pattern that identifies the beginning of a frame 152. The starting flag 160 is generated under firmware control of the transmitting communicator 60 during frame transmission, and is detected by firmware or hardware at the receiving communicator 60 during frame reception. In the preferred embodiment, the starting flag is unambiguous, so that no other sequence of bits in any transfer unit has the same pattern. This avoids the risk of commencing frame reception based on an arbitrary data byte in the middle of a body field. To achieve this in the preferred embodiment, the starting flag 160 is six ones, preceded and followed by a zero. This value is distinct from the preamble 146 (alternating ones and zeros), the postamble 150 (all zeros), the IFG 154 (all zeros) and the ending flag 166 (seven ones preceded by a zero). The uniqueness of the starting flag value is assured without restricting the use of any data values within the header 162 and body 164 fields of the frame 152 by "bit stuffing" within frames.

Bit stuffing is a technique that renders a predefined pattern of bits unambiguous by inserting bits at defined locations in an outgoing bit stream. The inserted bits prevent a predetermined bit pattern from occurring in locations other than those desired. Bit stuffing is commonly used, as it is in this situation, to render unique the delimiters of the frame boundaries. The portions of the frame 152 subject to bit stuffing in the frame shown in FIG. 8 are the header 162 and the body 164 fields. These fields are made unique by detecting when sequences of five or more one-bits that occur in the raw data that makes up these fields, and to insert ("stuff") a zero after any such sequence of five successive one-bits. In the preferred embodiment, the starting flag 160 and ending flag 166 include six and seven successive one bits, and because zero bits are stuffed after all other sequences of five successive ones in the other fields, the bit patterns of the starting flag 160 and ending flag 166 are unique within the transfer unit. In cases where variable amounts of transmission time are not desirable, a higher-overhead but fixed-length form of bit stuffing is to insert a zero bit after every fifth data bit in the header and body fields of the frame.

When bit stuffing is employed as part of frame transmission, "bit stripping" must be performed as part of frame reception. Bit stripping is the inverse operation to bit stuffing, thereby restoring the original bit pattern to the received data stream. Typically bit stuffing and bit stripping are collectively referred to simply as "bit stuffing." Bit stuffing is performed under control of the microcontroller 90 at the transmitting communicator 60 and bit stripping is performed under control of the microcontroller 90 at the receiving communicator 60.

The header 162 includes a number of fields which are described in conjunction with FIG. 9. The fields of the header contain several components of information which describe the structure and content of the frame 152.

As shown in FIG. 9, the first field in the header 162 is an organizationally-unique identifier (OUI) 172,

which is three bytes in the preferred embodiment. The OUI 172 is a constant value which is globally unique to the manufacturer of the communicator 60 and is preferably the identifier assigned to that manufacturer by the IEEE project 802 for LAN standardization. The primary operational purpose of the OUI 172 is that its value can be treated as a constant for further qualifying the validity of frame reception, shortly after detection of the starting flag 160 (FIG. 8).

The OUI 172 is followed by a communicator destination address or identification (CDID) field 170 which specifies the communicator 60 to which the frame 152 is directed, or a predetermined bit pattern which signifies that the frame is a broadcast intended for all communicators 60. The CDID 170 is 3 bytes in the preferred embodiment. The address or identification (ID) of each communicator 60 may be uniquely established in many different ways, such as by allocating a unique serial number to each one manufactured.

The OUI 172 and the CDID 170 constitute a standard, 48-bit, IEEE 802 compatible network address. Because the OUI 172 is unique, if a frame 152 having an unanticipated OUI 172 or CDID 170 is received, the receiving communicator 60 is alerted that the transmission came from an invalid source and should be disregarded, or that there was a transmission error and the transmission should not be acknowledged so that the transmission will be repeated. In accordance with IEEE 802 address format rules, the low-order bit of the OUI is set to zero for directed frame addresses and is set to one for broadcasts and multicast addresses. When used in the preferred embodiment, multicasts are not needed and broadcasts are indicated by the low-order OUI bit set to one and the CDID set to all zeros.

The communicator source address or identification field (CSID) 174 follows the CDID 170, denoting the transmitting communicator 60. The CSID 174 contains the unique ID of the source or transmitting communicator 60 which sent the frame 152.

Next is a frame type field 176 which contains a code that identifies the usage of the information in the body 164 (FIG. 8) of the frame 152. Frames 152 received successfully that have unrecognized frame type codes are acknowledged by the receiving communicator 60, but the contents of the body 164 of such frames 152 are ignored. The types of frames 152 which valid codes in the frame type field 176 include, Txop request frames, Txop grant frames, Txop relinquish frames, initial or primary information frames, basic control frames (which have no body 164), alternate information frames, hub handoff request frames, hub handoff acknowledgment frames, hub beacon frames, hub beacon reply frames, data packet frames from the hub to the remote(s) and data packet frames from a remote to the hub.

A sequence number field 178 occurs next in the frame 152. The sequence number 178 is a counter value which is incremented every time a communicator 60 sends a frame 152. The sequence number 178 allows the receiving communicator 60 to specify which frame (or frames) 152 needs to be resent in the event a transmission error or other problem. In the preferred embodiment, the sequence number is incremented by 1, modulo-256, after every frame 152 transmitted by a communicator 60. Frame acknowledgements and retransmission requests are based on this sequence number, so no more than 255 unacknowledged frames 152 must be permitted to be outstanding at any time. Retransmissions of unac-

knowledged or negatively acknowledged frames reuse the same sequence numbers as the original frame being retransmitted. Remotes **66** maintain one sequence value which is used and incremented for each transmitted frame **152**. Hubs **64** maintain sequence number values for the maximum number of communicators **60** allowed in the Group. One of these sequence values is used for information frames, outgoing broadcast data packet frames, and beacon frames, and the other sequence values are used for directed frames transmitted to each of the remotes **66** with allocated Txops.

An ending frame number field **180** follows the sequence number field **178**. The ending frame number field **180** is used in frames **152** sent from remotes **66** to hubs **64** to acknowledge the successful reception of a contiguous block of sequenced frames from the hub **64**. The value in the ending frame number field **180** is the highest (e.g., modulo-**256** with wrap-around) sequence number value of all successfully received frames **152** up to the latest sequence number that has been successfully received. The ending frame number field **180** is not used in frames **152** sent from hubs **66** to remotes **64**, because frames **152** sent by remotes **66** to the hub **64** during the inbound portion **74** of the communication cycle **70** (FIG. **3**) are acknowledged in the information frame sent by the hub **64** to the remotes **66** during the information interval **76** of the outbound portion **72** (FIG. 3) of the next communication cycle **70**. These acknowledgements in the information frame use the same format as this field (ending frame number).

A missing frame number field **182** follows the ending frame number field **180**. The missing frame number field is used in frames sent from remotes **66** to hubs **64** to indicate exceptions to the reception status reported in the ending frame number field **180**. The primary usage for the missing frame number field **182** is in cases where a Group of frames **152** in a transfer unit **144** has been successfully received, with the exception of one frame **152** somewhere prior to the end of the transfer unit. Under this circumstance, the ending frame number field **180** reports the sequence number of the last frame **152** within the transfer unit which was successfully received, and the missing frame number field **182** reports the sequence number of the single frame **152** prior to the reported last frame that was received in error. This permits significantly improved network efficiency in cases where only one frame **152** of a transfer unit is received in error, by permitting retransmission of only that one frame **152**, and not requiring retransmission of all subsequent frames **152** that have been received successfully. In cases where no such erroneous reception occurs, or where multiple erroneous transmissions were received, both the ending frame number field **180** and the missing frame number field **182** contain the same value (the sequence number of the last successfully received sequence of frames with no preceding erroneous frames). The missing frame number field **182** is not used in frames **152** sent from hubs **64** to remotes **66**, because frames sent from remotes **66** to the hub **64** during the inbound portion **74** (FIG. 3) of the communication cycle **70** are acknowledged in the information frame sent by the hub **64** to the remotes **66** during the information interval **76** of the outbound portion **72** of the communication cycle **70**. These acknowledgements in the information frame use the same format as this field (missing frame number).

A bandwidth allocation request (BWAR) field **184** occurs next in the header **162**. The BWAR field **184** is

used in frames **152** sent from remotes **66** to the hub **64** to indicate the amount of time needed to transfer all packets queued for transmission at that remote **66**. The request value is in units of basic time increments (BTIs). The value in the BWAR field **184** is zero if there are no queued packets awaiting transmission, and is **255** if **255** or more BTIs are needed to transmit the queued packets. The BWAR field **184** is not used in frames **152** sent from hubs **64** to remotes **66**, because all bandwidth allocation decisions are made at the hub **64**.

A bandwidth request flag (BWRF) field **186** follows the BWAR field **184**. The BWRF field **186** contains additional status information pertaining to the requested bandwidth allocation for frames to be sent from remotes **66** to hubs **64**. This field is not used in frames **152** sent from hubs **66** to remotes **64**, because all bandwidth allocation decisions are made at the hub **64**. Codes used in this field signify, for example, whether any frames have been waiting for transmission for more than two communication cycles **70** for reasons other than retries due to negative acknowledgement, whether any of the frames awaiting transmission are retries, whether the remote **66** is within a predetermined threshold of exhausting the amount of buffer memory available to hold frames queued for transmission, whether packets are queued from more than two different nodes **34** on the remote's directly-attached LAN segment **30**, and whether any broadcast frames are queued for transmission. These flags provide information useful to the hub's bandwidth allocation process, especially in cases where the network is saturated and not all bandwidth allocation requests can be granted.

The next field is a body length field **188** which signifies the length of the body field **164** (FIG. **8**) of the frame **152**. The code in the body length field **188** is an unsigned integer that indicates the number of data bytes in the body **164** of the frame **152**. This value includes all bytes from the first byte following the header **162** (FIG. **8**) to the last byte before the ending flag **166** (FIG. **8**), and does not include any bytes in the header **162**, starting flag **160**, ending flag **166** or CRC field **168**. Bits added by the bit stuffing (if any) are not counted in this length because they are added during transmission after the frame is formatted and are stripped at reception before the frame's fields are processed. The minimum body length is zero (for basic control frames), and the maximum body length is defined by the maximum number of bytes in the longest allowable frame, which is 1536 bytes in the preferred embodiment.

Next, a calibration parameters field **190** is used to transfer calibration parameter information between communicators **60**. The values in this field reflect the current readings for autonomous parameters, such as temperature, or the values during the last frame **152** received from the other communicator **60** for receive-specific parameters, such as RSSI. In general, values for the various parameters mentioned herein to secure proper operation of the RF modem **92** (FIG. **5**) may be contained in the calibration parameter field **190**.

The firmware at a communicator supporting the functionality of the RF modem monitors a plurality of calibration parameters supplied by the RF modem, and generates corresponding calibration responses to ensure proper transmitting and receiving operation whenever the RF modem is active. The aspects of the calibration activities that are visible at the protocol level include the need to communicate certain of the calibration parameters to the partner communicator in frame headers

162, the need for hubs to maintain separate calibration response values for each of the remotes that are currently active, and the need for a newly-active remote to conduct a signal acquisition procedure prior to requesting a Txop allocation from a hub.

The information that is available from the calibration process that may be used includes an RF AGC loop parameter which provides information regarding the level of received RF energy from another communicator on the same frequency channel, whether or not that communicator is using the same spreading code; and a received signal strength indicator (RSSI) parameter which describes the strength of the demodulated, despread received signal. The relative values of RF AGC and RSSI are useful in discriminating receptions from other communicators using the same frequency channel but a different spreading code, from communicators on the same frequency channel that employ the same spreading code and hence are members of the Group. In addition, other calibration parameters include a Costas loop parameter, a RF synthesizer loop parameter, a temperature for the oscillator circuitry of the RF modem, an in-phase signal (I magnitude) parameter, a quadrature phase signal (Q magnitude) parameter, and a delay locked loop (DLL) parameter. Calibration parameter responses include: a Costas loop preset value, a RF synthesizer loop preset value, a RF AGC loop preset value, a RF oscillator bias value, a delay locked loop bias value, a baseband AGC preset value, a baseband AGC reference value, and a RF AGC reference value.

Several additional digital signals are defined for use as part of the signal acquisition process between the hub and the remotes, and these acquisition signals are presented in conjunction with the calibration parameter responses. The signal acquisition responses include one used to select between the two available antennas of the RF modem, two used to enable information for controlling the usage of the preset calibration parameter values by the RF modem circuitry and two weighting controls used to distinguish signal acquisition (during the preamble) from normal reception.

As shown in FIG. 8, the body **164** of the frame **152** follows the header **162**. The body contains information specific to the particular frame type identified in the type field **176** (FIG. 9) of the header **162**. In the case of data packet frames, the body will be an encapsulated LAN packet from the LAN segment **30** that is being bridged by the communicators **60** or a LAN packet directly from the attached resource in cases where the communicators are being used as network adapters rather than as bridges. In the case of control, information, and beacon frames, the contents of the body **164** provide control information to communicators **60** receiving the frames.

An ending flag **166** follows the body **164** of the frame **152** and, similar to the starting flag **160**, the ending flag **166** is a unique bit pattern that provides unambiguous identification of the end of a frame **152**. In the preferred embodiment, the value of the ending flag **166** is represented by seven consecutive one bits preceded by a zero bit and, thus, is distinct from the preamble **146** (alternating ones and zeros), the postamble **150** (all zeros), the IFGs **154** (all zeros) and the starting flag **160** (six ones preceded and followed by zeros). Like the starting flag **160**, the uniqueness of the value of the ending flag **166** is guaranteed without restricting the use of any data values within the header **162** or body **164** fields of the frame **152** by bit stuffing within the header **162** and body **164** fields of the frame **154**. The ending flag **166** is generated by the transmitting communicator **60** during frame transmission, and is detected by the receiving communicator **60** during frame reception.

The last field of the frame **152** is a cyclic redundancy check (CRC) field **168**. The CRC field **168** provides for the detection of communication errors in the physical transmission by providing a CRC word generated by the transmitting communicator and checked by the receiving communicator **60**. The value in the CRC field **168** covers all bytes from the first byte after the starting flag **160** through and including the ending flag **166**. Cyclic redundancy checking is known in the art, but in the preferred embodiment, the CRC value is calculated by the polynomial $x^{16}+x^{15}+x^2+1$, also known as CRC-16. The CRC logic in the communicators **60** is designed in a manner that the CRC remainder value is zero after reception of an error-free frame. The use of a CRC code, which allows error detection but not error correction, is based on the high data reliability provided by the preferred form of the RF modems described above. In cases where data reliability on the RF link is worse than about one in **106**, the use of an error-correcting code, such as a Reed-Solomon code, is recommended for the contents of the CRC field.

Four different types of frames are used to establish communications in accordance with the protocol of the present invention. The four types of frames are information frames, control frames, data packet frames and beacon frames. Information frames are used to broadcast communication cycle control information from the hub to the remotes. Control frames are used for bilateral transfer of protocol control information between communicators. Data packet frames contain substantive data, such as the LAN packets which are being bridged between LAN segments **30** or transferred between nodes **34** by the communicators **60**. Beacon frames are transmitted by hubs **64** so that adjacent hubs can detect each other's presence. Each of these four types of frames is described in detail below.

There are two information frames. A primary information frame is transmitted during the information interval **76** of the communication cycle **70** shown in FIG. 3. An alternate information frame is transmitted during the alternative information interval **82** of the communication cycle. The primary and the alternate information frames are identical and are described below. However it should be noted that the portions of the information frames which specify usage during the broadcast interval **78** and the directed interval **80** will be meaningless if a remote first successfully receives the alternate information frame during the alternative information interval **82**, because the broadcast and directed intervals will have passed before the information is available. Thus communicators which only receive the alternate information frame must ignore the information relating to the broadcast and directed intervals of the communication cycle.

In the case of an information frame, its frame type field **176** (FIG. 9) contains a value which distinguishes it from the other types of frames. The body field **164** (FIG. 8) of the information frame contains all of the information needed by remote communicators to participate in communication in accordance with the communication cycle **70** shown in FIG. 3. The body field of an information frame includes a number of different fields which provides information describing each of the following types of information: (1) the number of Txops **84**

which are currently allocated; (2) a security level established for the communication with the Group, for example, to allow any communicator to join or leave the Group, to limit the size and participants of the Group to a predetermined number or to predetermined ones of communicators, or the like; (3) acknowledgement (ending frame number/missing frame number) information to each remote communicator which has been allocated a Txop; (4) the number of BTIs in the present communication cycle; (5) the number of BTIs in the next communication cycle; (6) the number of BTIs in the communication cycle after the next communication cycle; (7) the number of BTIs for the broadcast interval **78**; (8) the number of BTIs from beginning of the present communication cycle to the transmission time of for any directed packets sent during the directed interval **80** to each remote which has been allocated a Txop, including a code for remotes which have allocated Txops but for which the hub has no outbound directed packets pending for transmission; (9) the number of BTIs from beginning of the present communication cycle until start of inbound portion **74** of the communication cycle; (10) the number of BTIs from beginning of alternative information interval **82** until start of the inbound portion **74** of the communication cycle; (11) the number of BTIs from beginning of inbound portion **74** of the communication cycle to the beginning of the allocated Txop for each remote which has been allocated a Txop, including an entry for all of the allowable Txops, regardless of whether the Txop has been allocated to a remote; (12) the number of BTIs of duration for each allocated Txop; (13) the number of BTIs from beginning of the inbound portion **74** (FIG. **3**) of the communication cycle to the start of the Txop request interval **86** of the communication cycle; (14) the number of BTIs from the beginning of the inbound portion **74** to the start of hub beacon interval **88** of the communication cycle (FIG. **3**), with an indication if the communication cycle will not include a hub beacon interval; (15) a code indicating characteristics of the hub, to be used for communicators to arbitrate between one another to establish a new hub or to confirm the selection of the existing hub, including information describing whether the existing hub is operating from AC power or batteries, whether the communicator is configured as hub or has assumed hub operation due to lack of a better candidate communicator, whether a resource attached to the local LAN segment of the communicator is a LAN server; (16) the number of active nodes on the local LAN segment attached to the communicator; (17) the name of the Group; and (18) a bit map of the LAN node IDs in use on all of the LAN segments bridged together by the present invention (only if bridging is being performed).

The various information in the body of the information frame provides the remote communicators with the basis for their RF communication activities for the remainder of the communication cycle. Of special significance are the various items that define the starting times and durations of the subsequent intervals of the present communication cycle and the lengths of the next two communication cycles. The information frame, in addition to conveying the information described above, also provides the information by which the remotes remain synchronized with the hub for the purposes of turning their RF transmitters and receivers on and off. The start of the information frame (or alternate information frame if the remote is unable to successfully receive the information frame) serves as the datum from which the starting times of all other intervals within the communication cycle are measured.

Each remote communicator uses an internal clock, maintained by its microcontroller **90**, to measure times until significant events (such as the expected arrival of frames to be received from the hub and the start of the allocated Txop) relative to the time that the information frame was received. The importance of correct measurement of those times necessitates frequent resynchronization of the remotes to the sense of time promulgated by the hub. This is because the clock oscillators on each of the communicators will necessarily will operate at slightly different speeds, so the time measurement on these communicators will "drift" apart the longer it has been since they were last synchronized.

Commonly available, low cost quartz crystals provide oscillators that are accurate to ±0.01%, which can result in up to 100 microseconds of clock drift per second. A reasonable goal for inter-communicator synchronization is not over 10% of the BTI duration. In the preferred embodiment, the BTI is 4 milliseconds, so that the permissible clock skew is 400 microseconds, allowing communication cycles up to about 2 seconds in total length.

This upper bound on the length of the communication cycle defines the worst case uncertainty as to when receivers must be enabled to be sure to be active in time to receive expected transmissions. By re-synchronizing all communicators in the Group sufficiently often, this uncertainty can be kept small enough to avoid reducing network throughput due to extremely long delays to combat timing uncertainty.

For each interval within the communication cycle of interest to a particular remote, the remote must measure the time, from receipt of the information (or alternate information) frame until the interval of interest, using the appropriate count of BTIs from the body of the information (or alternate information) frame. Each remote may make autonomous decisions about whether to disable or power down portions of its circuitry based on its own power consumption characteristics, power supply characteristics (AC vs. battery, amount of battery charge remaining, etc.), and the amount of time between events of interest. As a minimum, each active remote must attempt to receive each information frame, and must attempt to receive the alternate information frame whenever it is unable to successfully receive the information frame, for a given communication cycle.

Another key reason that the receipt of information frames is critical is that the lengths of communication cycles are constantly changing, as is discussed below. In order for a remote to remain in contact with its hub, the remote must know the duration of the current communication cycle. This duration, as well as the durations of the next two communication cycles, are reported in each information frame. This provides a reasonable margin for RF communication errors, since, at a minimum, a remote must successfully receive one information frame or alternate information frame out of every two communication cycles (1 out of 4 such frames) to remain synchronized with the hub. Because the remotes all have their RF modems active to receive each information frame, the hub also uses this frame to send all acknowledgements and bandwidth allocations.

A number of different types of control frames are employed. Those include a basic control frame, a Txop request control frame, a Txop grant control frame, a Txop relinquish control frame, a hub handoff request

control frame, and a hub handoff acknowledgement control frame. Each is described below in greater detail.

The basic control frame is used by remotes for non-piggybacked acknowledgements (acknowledgements to outbound directed frames when there are no inbound frames on which to piggyback these acknowledgements), bandwidth requests when the allocated Txop is too short to accommodate any of the messages which it has queued for transmission, and to prevent the loss of the allocated Txop due to inactivity when no LAN traffic is occurring on its attached LAN segment. The basic control frame utilizes the header field **162** (**FIG. 8**) with a zero-length body field. The acknowledgement and bandwidth request fields in the header ordinarily contain non-null information.

Each remote in the Group requests a Txop allocation from the hub when that remote becomes active or enters the communication space of the hub. Each remote must obtain a Txop allocation prior to engaging in data communication over the RF network. A Txop will be allocated by the hub on the next communication cycle unless all available Txops are in use. A Txop **84** (**FIG. 3**) is a fixed position in the order of Txops within the inbound interval **74** (**FIG. 3**), but a Txop is not a fixed amount of transfer bandwidth on any particular communication cycle. The hub allocates Txops to remotes in the order Txop requests are received. Once allocated, a remote retains its Txop until relinquished explicitly by a control frame from the remote to the hub or until relinquished implicitly from non-usage by the remote for a predetermined number of communication cycles. The maximum number of Txops which can be allocated by a hub is the maximum number of concurrently operable remote communicators in the Group. In the preferred embodiment, using RF modems with a 382 Kbps data rate, a reasonable maximum size is 16. With higher-speed RF modems, the number can be greater.

The Txop request frame is used by newly active remotes to request a Txop allocation from the hub. Since the remote does not have a Txop in which to send this request, the Txop request frame is sent in the Txop request interval **86** (**FIG. 3**). This interval occurs immediately after the completion of the last of the inbound Txop communication cycle.

Sending the Txop request control frame in the described manner during the Txop request interval **86** (**FIG. 3**) may result in successful communication between the remote and the hub, or may result in a destructive collision if multiple remotes are sending Txop request frames simultaneously. If the hub fails to respond with a Txop grant control frame (either positive, allocating a Txop, or null, indicating the unavailability of any Txops) within a predetermined number of subsequent communication cycles, the remote will repeat the Txop request frame after expiration of a random number (e.g., one to eight) of communication cycles. By retrying at random intervals, the probability of repeated collisions among multiple, concurrent requesters is reduced to an acceptably low level. In the case of Groups operating with a dynamically selected hub, the response of the hub to the Txop request frame may be a hub handoff request frame in cases where the hub arbitration fields of the Txop request frame indicate to the active hub that the new communicator sending the Txop request frame is a better choice to be the network hub.

The Txop request control frame utilizes a number of fields in the body **164** (**FIG. 8**) to convey the information necessary for performance in accordance with the present protocol. The body of the Txop request frame includes fields containing codes which convey the following types of information describing the characteristics of the communicator sending the Txop request frame: (1) hub arbitration information describing whether the communicator is operating on AC power or battery power; (2) whether the communicator is configured to operate as a hub; (3) whether any resource on the communicator's directly attached LAN segment **30** is a network server; (4) the number of active nodes on the directly attached LAN segment **30**; (5) the name of the Group (to permit detection of name conflicts between Groups); and the name of the communicator (assigned by the user) to facilitate network statistics gathering and administration.

The Txop grant control frame is generated by the hub in response to a Txop request frame received by the hub during a previous communication cycle. The Txop grant frame also utilizes the body of the frame to hold a field containing a code indicating the transmission Txop number which the hub has allocated to the remote communicator sending the Txop request frame. A Txop number of zero indicates denial of the Txop request.

The Txop relinquish control frame is sent by a remote to the hub to indicate that the remote sending the Txop relinquish control frame will cease using its allocated Txop. This information is communicated solely by the header of this frame, so the body length field is zero.

The hub handoff request control frame is sent by the existing hub to a remote which the hub has determined is more suitable for acting as the hub for the Group. The hub handoff request frame is a request that the remote communicator addressed by this frame accept responsibility as the hub and to thereafter control communications by managing the communication cycles. The hub which sends the hub handoff request frame will have determined that the remote to which the this request is addressed is better configured to serve as the hub, based on the hub arbitration information contained in the Txop request frame previously sent by the communicator as compared to its own hub arbitration information, contained in its information frame. The hub handoff request control frame includes a sufficient number of fields in its body to convey the request and other information needed by the remote to accomplish the handoff of hub operation. This information includes various traffic and calibration parameter values.

The handoff acknowledgement control frame is sent by the remote to the hub in response to the receipt of a hub handoff request frame. The handoff acknowledgement frame indicates the fact that the remote will become the hub or the rejection by the hub of the handoff request.

The data packet frame is employed to convey network data in the body field of the frame. The data for the body of the data packet frame is usually a LAN packet being bridged to or from the local LAN segment or a LAN packet from the attached resource in cases where the communicators are serving as LAN adapters rather than network bridges. Directed data packet frames sent from a remote to a hub are addressed to the destination communicator (CDID). Broadcast data packet frames are sent by a remote to the hub when the hub is to retransmit the data packet frame as a broadcast or a multicast to all communicators in the Group. The CDID of a directed packet frame sent by a remote is that of the hub if the ultimate destination is to a node on the local LAN segment directly connected to the hub.

The CDID of a directed data packet frame sent by a remote to the hub is that of another remote communicator if the ultimate destination is to a node on another remote LAN segment and the hub is only to serve as a frame repeater in conveying the data packet frame to its ultimate destination. The source address (CSID) of the data packet frame sent by a remote to the hub is always the ID of the remote. For data packet frames sent by the hub to a remote, these frames are addressed to the remote destination communicator, or if the data packet is to be broadcast or multicast, to an address indicating a broadcast or a multicast. The destination address (CDID) of the directed data packet frame to the remote is the address of the remote communicator for all non-broadcast data packet frames. The source address (CSID) is unmodified if the hub is repeating a data packet frame previously received from another remote. The CSID is the address of the hub communicator if the body portion of the data packet frame originated from the LAN segment directly attached to the hub.

Two different types of hub beacon control frames are employed in the protocol of the present invention. A hub beacon frame is transmitted to identify the fact that the existing hub is functioning as a hub for the Group. The body portion of the hub beacon frame contains sufficient information to present all of the relevant information concerning the characteristics and the functionality of the hub. The hub beacon frames are sent using a special inter-hub spreading code used solely for this purpose and never used for hub-to-remote transmissions. Upon receipt of the hub beacon frame by another hub operating on the same frequency channel within the RF range of the first hub, the other hub will transmit a beacon reply frame. The beacon reply frame constitutes a recognition of a possible conflict in operation between the two hubs. The beacon reply frame sent by the other hub also contains the relevant information concerning the characteristics and the functionality of the other hub and is also sent on the special inter-hub spreading code. Based on the information contained in both the hub beacon frame from the first hub and the beacon reply frame from the other hub, the hubs will attempt to adjust their operational characteristics to avoid RF transmission conflict. Because each newly-active hub seeks a clear frequency channel prior to listening for hub beacon frames, the detection of and reply to the hub beacon frame will only occur if the hubs must share a single channel. Upon establishing such communication, the two hubs attempt to negotiate a sharing of the available bandwidth on the single channel by adjusting the length of their respective communication cycles to place their information intervals **76** at different times and by assigning limited (roughly half) of the time in their inbound portions **74** to Txops such that the unassigned portions are free for allocation by the other hub for remotes in the Group.

Acknowledgements are generated for all directed data packet frames. Broadcast data packet frames, information frames, and beacon frames are not acknowledged. Control frames are implicitly acknowledged through control activity, such as bandwidth allocation, Txop assignment or frame re-transmission. The acknowledgements from hub to remote are sent in the information frames. The acknowledgements from remote to hub are piggybacked on subsequent data packet or control frames if possible, but are conveyed in basic control frames if no other pending frames are available.

Positive acknowledgements and negative acknowledgements must be generated during the communication cycle immediately following the communication cycle in which the frame which is being acknowledged was transmitted. Non-acknowledgement for two communication cycles is treated as equivalent to negative acknowledgment by the source communicator. Retransmission of negatively acknowledged frames is the highest priority for allocated bandwidth. Retransmissions must occur during the first available Txop (of sufficient length) following the negative acknowledgement.

The information, control, data packet and hub beacon frames are employed in the communication cycle **70** in a manner that is more readily understood from FIG. **10**. The communication cycle **70** shown in FIG. **10** is the same as that previously shown in FIG. **3**, but is presented in an elongated form in FIG. **10**. As shown in FIG. **10**, the communication cycle **70** is subdivided into the outbound portion **72** used for transmission by the hub to the remotes and the inbound portion **74** used for transmissions by the remotes to the hub. Since all transfer units pass through the hub **64**, remotes **66** only need to have their RF modems **96** enabled for frame reception during the relevant segments of the outgoing portion **72** of the communication cycle **70**, and then need to have their RF modems **96** enabled for frame transmission only during the allocated Txops of the inbound portion **74**. As a result, power may be conserved, which is especially important when the communicators **60** are powered by batteries.

As is shown in FIG. **11**, the frames transmitted by the hub **64** during the information interval **76**, the broadcast interval **78** and the directed interval **80** are all sent as a single transfer unit **144**. The preamble **146** and postamble **150** introduce and conclude the transfer unit **144**. The information frame **200**, sent during the information interval **76**, the broadcast data packet frames **202** destined to all of the remotes, sent during the broadcast interval **78**, and the directed data packet frames **204** addressed to specific remotes **66**, sent during the directed interval **80**, constitute the payload **148** (FIG. **6**) of the first transfer unit **144** sent by the hub **64** during the outbound portion **72** of each communicator cycle **70**. By including the frames of the information interval **76**, broadcast interval **78** and directed interval **80** together in one transfer unit **144**, power consumption is optimized at the remotes **66** and network overhead for preambles and postambles is minimized. Since each remote **66** is required to enable its RF modem **96** to receive the communication cycle information during the information interval **76**, each remote **66** simply leaves its RF modem **96** enabled for the duration of the outbound broadcasts (if any) and directed packets to its address, based on the appropriate fields from the information frame **200**.

The second transfer unit **144** sent during the outbound portion **72** is a one frame transfer unit containing the alternate information frame, that repeats the information from the information frame **200** sent earlier during this communication cycle. The alternate information frame is sent in a separate transfer unit to permit the RF modems **96** at each remote to be able to re-acquire and re-synchronize to the incoming RF signal, thereby minimizing the risk of errors in receipt of the alternate information frame **206**. The information defining the communication cycle is repeated in the alternate information frame due to its importance in synchronizing all

of the remotes 66 to the hub's clock for proper timing of the start of events occurring during the communication cycle 70, thereby assuring the integrity of communication during the communication cycle 70. Remotes 66 that successfully received the information frame 200 for the current communication cycle 70 do not have to receive the alternate information frame 206.

The information interval 76 includes the preamble of the first transfer unit 144 sent during the outbound portion 72 and the primary information frame 200 which contains the communication cycle information, as shown in FIG. 12. The information frame 200 contains all of the information needed by remote communicators 66 to participate in the communication defined by the MAC protocol of the present invention. Information in the information frame 200 includes the length of the outbound and inbound portions of the communication cycle 70 measured in BTIs, the duration and destinations of outgoing frames sent during this communication cycle, acknowledgements to incoming frames received during the previous communication cycle 70, allocation of Txops to the remotes 66 during the inbound portion 74 of this communication cycle 70, and calibration parameters of the hub communicator 64 that permit adjustment of the remote communicators 66 to receive hub transmissions with the best achievable reliability.

Based on the information conveyed in the information frame 200, all remotes 66 enable their RF modems 96 at the time of the expected arrival of each information frame 200. Also based on the contents of the information frame 200, each remote 66 is able to determine when to enable its RF modem 96 for receiving transmissions, during the broadcast interval 78 and appropriate portions of the directed interval 80, and when to enable its RF modem 96 for transmissions, during its allocated Txop of the inbound portion 74. Acknowledgements of successful receipt of frames sent from the remotes 66 to the hub 64 occurring during the preceding communication cycle 70 are also included in the information frame 200. These acknowledgements information the remotes 66 of the need to retransmit some of the frames that were sent during the preceding communication cycle 70, or indicate that the remotes 66 can reclaim the buffers holding those frames because the hub successfully received them.

Because many items in the information frame 200 must be interpreted by the remotes 66 in real time, a longer IFG 154 is used between the information frame 200 and the next frame in the hub's transfer unit.

Broadcast data packet frames received by the hub 64, either from its locally attached LAN segment 30 or from a frame sent by a remote during the preceding communication cycle, are sent in broadcast frames 202 by the hub 64 immediately after the IFG 154 following the information frame 200. This optimizes power utilization at the remotes 66, because each remote 66 must enable its RF modem 96 to receive the information frame 200, and can leave the RF modem 96 enabled for the immediate reception thereafter of the outbound broadcast frames, if any, as indicated by the information frame.

Packets received by the hub 64 that are not addressed to nodes 34 on its local LAN segment 30 are transmitted during the directed interval 80 to the designated remotes 66 in directed frames 204 during the outbound portion 72 of the communication cycle 70 immediately following the cycle during which they were received.

The outgoing packets in the directed frames 204 are ordered by Txop 84 allocations. All directed data packet frames being sent to a particular remote 66 during any communication cycle 70 are transmitted sequentially (and in the order received). The information frame 200 indicates the relative starting time and absolute duration of the directed frames 204 to each remote 66 in the Group.

Remotes 66 with no pending directed data packet frames to receive, as indicated in the information frame, may disable their RF modems 96 after the outgoing broadcast interval 78, leaving them disabled until the anticipated arrival time of the next information frame 76. A determination is made at each remote 66 having directed packets pending to be received whether to leave the RF modem 96 enabled for reception, or to disable the RF modem 96 after the broadcast interval 78 and then to re-enable the RF modem 96 at the assigned time to receive directed packets addressed to them. This determination may be based on the type of active power source, for example, batteries or commercial power, and the power consumption versus time characteristics of the communicator 60.

Because of the critical nature of some of the contents of the information frame 200, especially the communication cycle duration, frame acknowledgement, directed frame timing, and Txop timing, and Txop allocation data, there is a potentially significant impact upon communications efficiency if one or more remotes 66 in the Group do not successfully receive an information frame 200. To reduce the risk of such non-reception, with little added overhead, the alternate information frame 206 is broadcast during the alternate information interval 82. The alternate information frame contains the same information as the primary information frame 200, is transmitted by the hub 64 in a separate transfer unit after the transfer unit containing the information from the information, broadcast and directed intervals has been sent.

A predetermined minimum time separation of the information frame 200 and alternate information frame 206 is provided, even in the absence of any outgoing broadcast or directed packets. This time period is determined to enhance the probability that a remote communicator which did not successfully receive the first information frame 200 receives the alternate information frame 206. Sending the alternate information frame 206 in its own transfer unit 144 with a separate preamble 146 achieves some of this time separation and may be needed to achieve reliable signal acquisition in some RF environments. Although the alternate information frame 206 is an exact copy of the primary information frame 200, the information conveyed during the broadcast and directed intervals will not be available to any remotes that utilize the alternate information frame 206. The information transmitted during the broadcast and directed intervals will have been lost prior to the remotes 66 obtaining the necessary information from the information frame 200 to participate in the communication cycle 70. Nonetheless, the lost information relevant to that remote from the directed interval 80 can be retransmitted pursuant to negative acknowledgement or lack of acknowledgment from this remote, which involves considerably less risk of overall communication failure than if the remotes 66 do not operate as expected during their portions of the communication cycle 70.

At the conclusion of these intervals of the outbound portion **72** of the communication cycle **70**, the remotes **66** are permitted to transmit transfer units to the hub **64** during the inbound portion **74**. FIG. **12** illustrates the separate transfer units from the remotes **66** transmitted during their allocated Txops **84**. When the time for the Txop **84** of a remote **66** arrives, that remote **66** may send as many frames as permitted by the time allocated for this Txop in this communication cycle. In the absence of any frames awaiting transmission, the remote **66** may leave its Txop unused, or may send a control frame. The purposes of such control frames include acknowledging previous frames received from the hub **64** (although such acknowledgements normally would be piggybacked on inbound frames directed to the hub **64** from the remote **66**), requesting a change in bandwidth allocation from the hub **64**, and preventing this remote's Txop allocation from being expunged due to inactivity. At the conclusion of the Txop intervals **84** during the inbound portion **74** of the communication, remotes which have just joined the Group may request a Txop allocation. The Txop request is made in a one frame transfer unit shown in FIG. **13**. This transfer unit includes the preamble **246**, a Txop request frame **151**, and a postamble **150**.

At predetermined time intervals, for example every five seconds, a additional interval known as a hub beacon interval **88** is added at the end of the communication cycle. This interval is used for communication among nearby Groups in an attempt to avoid destructive interference between adjacent hubs that must use the same frequency channel. At the beginning of the hub beacon interval, a hub beacon frame **149** is transmitted in the transfer unit shown at the beginning of the hub beacon interval shown in FIG. **14**. This transfer unit is sent using a special inter-hub spreading code. The remainder of this interval is used to listen on the same inter-hub spreading code for hub beacon reply frames **145** from other, nearby hubs. Thus, the transfer units transmitted during the hub beacon interval may be both inbound and outbound. The hub beacon intervals are inserted periodically at the end of communication cycles to occur so that not more than predetermined number of seconds elapse between the transmission of successive hub beacon frames by each hub.

There are a number of different operational aspects of the MAC protocol of the present invention which pertain to the communication cycle. Many of these operational aspects involve variations in the amount of time for the communication cycle itself and the intervals within the communication cycle. Details regarding these operational aspects are discussed below.

The duration of each communication cycle is adjusted to vary from the duration of the preceding and following cycles. The duration is adjusted by the hub following the rules outlined below. Each hub adjusts the duration of communication cycles such that successive cycles are never of equal length, in order to avoid possible interferences with a hub's transmissions created by regularly occurring noise and to minimize periodic interference with other RF devices due to this hub's transmissions. The adjustment rules seek to create the greatest amount of useful communication bandwidth while permitting the remotes to operate with their RF modems energized for minimum transmission and reception on-time. It is necessary for battery operated remotes to recognize when to expect the beginning of the next communication cycle, in order to power-up their RF modems to receive the information frames at the beginning of each cycle. To facilitate this knowledge, the hub transmits the lengths of each of the next two communication cycles as part of the information frame at the beginning of each communication cycle. Including the lengths of the next two cycles in each information frame permits remotes to remain adequately synchronized with the hub in cases where up to three successive information and alternate information frames are not successfully received.

The adjustments to the communication cycle involve the use of a coarse adjustment rule set and a fine adjustment rule set, operating simultaneously. The coarse adjustments establish the base cycle time duration of the communication cycle, using parameters such as the number of Txops allocated, the aggregate amount of traffic during recent cycles, and the number of remotes involved in sending that traffic. The fine adjustments establish the random variations in the length of successive communication cycles. These variations are relative to the base cycle time duration set by the coarse adjustment. The fine adjustment creates the time diversity for communication. With the resulting length randomization, interference between nearby Groups that cannot detect each other using the hub beacon and hub beacon reply frames or from a noise source having cyclic, but non-continuous transmissions, is not catastrophic to communication within the Group.

The time duration of each communication cycle is determined by the addition of a base time component and a fine random component. Latency adjustment rules establish the base time component and the fine random component is established relative to the base component. Both adjustment rules are described below.

The coarse adjustment involves changing the base cycle duration based on information relating to the number of remotes with allocated Txops and the subset number of those remotes that are requesting, or have recently used, communication bandwidth. The goal of the latency adjustment rules is to reduce power consumption by remotes during periods of little communication, while accepting the associated increase in communication latency during such periods of low usage. Dynamic compensation reduces this latency when the demand for communication bandwidth increases. This start-up latency at an increase in traffic levels is analogous to the spin-up delay that occurs prior to handling hard disk accesses on a portable personal computer that has stopped its disk drive motor as a power conservation measure.

The coarse latency adjustment of the base cycle duration is determined using a piecewise function whose default values are listed in the Table below. The vertical axis of this Table is Nfree, which is the number of unallocated Txops, using the example of 16 possible communicators in the Group. Generally the value Nfree is 15 minus the number of allocated Txops, since the hub will be one of the communicators is the Group. However, there are certain cases, such as conferences and managed Groups using roster security, where there can be a known total of allocatable Txops that is less than 15. The horizontal axis of this table is Nactv, which is the peak number of remotes that have requested a Txop allocation longer than the default duration during the present communication cycle or which have sent or received one or more directed data packet frames within a predetermined number of previous communication cycles.

The values obtained from the Table are the number of coarse adjustment units in the base communication cycle. Each coarse adjustment unit is a predefined (parameterized, with a default value of 16) number of basic time increments (BTIs).

message traffic at the hub may well cause a subsequent increase in the outbound portion of the communication cycle to compensate for this increase.

If the maximum time duration of a communication cycle is insufficient to send all pending frames, the situa-

LATENCY ADJUSTMENT TABLE

	Nactv															
Nfree	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	9	7	5	5	5	6	6	8	8	8	10	10	10	12	12	12
1	9	7	5	5	5	6	6	8	8	8	10	10	10	12	12	—
2	10	7	5	5	5	6	6	8	8	8	10	10	10	12	—	
3	10	7	5	5	5	6	6	8	8	8	10	10	10	—	—	—
4	11	8	5	5	5	5	6	7	8	8	10	10	—	—	—	—
5	11	8	5	4	5	5	6	7	8	8	10	—	—	—	—	—
6	12	8	5	4	5	5	6	7	8	8	—	—	—	—	—	—
7	12	8	5	4	4	5	6	7	8	—	—	—	—	—	—	—
8	13	9	5	4	5	5	6	7	—	—	—	—	—	—	—	—
9	13	9	5	5	5	6	6	—	—	—	—	—	—	—	—	—
10	14	9	5	5	5	6	—	—	—	—	—	—	—	—	—	—
11	14	9	5	5	5	—	—	—	—	—	—	—	—	—	—	—
12	15	10	5	5	—	—	—	—	—	—	—	—	—	—	—	—
13	15	10	5	—	—	—	—	—	—	—	—	—	—	—	—	—
14	15	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

The fine adjustment involves lengthening the current communication cycle by a randomly selected number of basic time increments, subject to limitations that keep this variation to be less than one coarse adjustment unit. For each communication cycle, the randomization value is a random number between 0 and one less than the number of BTIs in a coarse adjustment unit.

An allocation decision made within any communication cycle is the division between the outbound portion **72** and the inbound portion **74**. The overall restrictions on the division between the outbound and inbound portions include the recognition that the communication cycle must never exceed a predetermined maximum amount of time and must never be less than a predetermined minimum amount of time. The maximum predetermined amount of time is established in accordance with the objectives of how frequently it is desired that a communication cycle occur, and in recognition that timing requirements particular to the higher layer LAN functionality of the LAN protocols in use on the attached network segments **30** must be met with respect to the bridging of LAN segments. The minimum length of time that must be provided for the inbound portion of any communication cycle is one BTI per Txop for transmission of a basic control frame to send acknowledgements and bandwidth requests. When a hub beacon interval is provided, the time available for this interval is obtained by reducing the time allocated for inbound Txops, even though the hub beacon frames are sent by hubs.

If the maximum time duration of a communication cycle is sufficient for transmitting all of the queued frames at the hub, plus all requested Txops for the remotes, plus a defined number (typically 1–4) BTIs per allocated Txop for remotes that are not requesting Txops, plus the hub beacon interval if needed, the outbound portion is allocated to be the length needed to transmit all of the queued frames at the hub. This condition is referred to as a non-saturated condition. By allocating the extra time to inbound portion with preference to the remotes with the largest magnitude of pending transmission requests, a rapid increase in inbound message traffic to the hub might generate a backlog of frames awaiting transmission at the hub. The increase in

tion is described as a saturated condition. In the case of a saturated condition, a determination must be made as to which frames will be transmitted first. The priorities for making such decisions are described below, generally in descending order of importance. In other words, attempts will be made to satisfy the first itemized considerations prior to satisfying the last itemized considerations.

First of all, it is mandatory that sufficient time be allocated for the transmission of the complete information **200** and alternate information **206** frames during their intervals in the outbound portion **72** of the communication cycle **70**, and for the hub beacon interval **88** (if needed during that communication cycle), and for at least one BTI per allocated Txop during the inbound interval. Secondly, sufficient time must be provided for transmitting all directed data packet frames already queued at hub during the directed interval **80** of the communication cycle **70**. Third, sufficient time should be provided during the remote Txops for at least four BTIs per remote requesting a Txop, plus if possible, time to handle the full requested Txop length for one or more of the remotes requesting more than this amount of time (e.g. greater than 4 BTIs). These longer inbound allocations are granted to the remotes in order of descending request length. Fourth, sufficient time should be provided to transmit all queued broadcast data packet frames during the broadcast interval **98**. Lastly, time will be provided for any other transmissions, including outbound directed data packet frames queued at hub after the saturation occurred.

Another adjustment which occurs within the inbound interval is the bandwidth allocation to each remote during its Txop **84**. This bandwidth allocation controls the time duration length of the Txop. Even if a remote has requested and been allocated a Txop, the hub may adjust the length of the Txop during each communication cycle based on a number of different factors, including the aggregate traffic levels during recent communication cycles, the amount of data awaiting transmission at each remote with an allocated Txop, the elapsed time since the last Txop of the remote. Both the number and length of Txops are under control of the

hub, and may be allocated in a manner that provides most of the available bandwidth to the communicators with the most traffic at each point in time. The allocation should provide an approximately fair sharing of bandwidth during periods of network saturation, while not limiting the burst nature of typical, nonsaturated LAN traffic patterns.

During any communication cycle, some remotes with allocated Txops may not be allocated any extra time for its Txop although every remote has, at least, the minimum-length Txop described above for the purpose of sending a control frame to acknowledge frames received from the hub and/or to request the allocation of a longer Txop to transmit queued, outgoing data packet frames.

When a remote's Txop arrives, that remote may send a single transfer unit that contains as many frames as the allocated Txop permits. In the absence of any frames awaiting transmission, the remote may leave its allocation unused, or may send a control frame. The purposes of such control frames include acknowledging previous hub transmissions in cases where there is no frame traffic in the direction of the remote to the hub on which to piggyback the acknowledgement, requesting a change in bandwidth allocation by the hub, and preventing the allocation from being expunged due to non-use.

The protocol of the present invention is preferably implemented as a state machine through the use of the microcontroller **90** and instructions contained in the memory of each of the communicators, the ROM **92** and the RAM **94** (FIG. **4**). A state diagram representing the overall operation of a communicator is shown in FIG. **15**.

Upon being first powered on, the communicator will reside in an initialization state (Listen RF) **250** with its RF modem activated for reception to "listen" for RF activity on predesignated possible frequencies and codes. Operational states of the communicator occurring prior to the Listen RF state are primarily activation and inactive states which have relevance to the communication occurring on the local LAN segments, and these states have been described in the aforementioned application which is incorporated herein by reference.

Generally in the Listen RF state **250**, the communicator operates with the RF modem in a receiving mode, active to receive incoming transfer units. The communicator attempts to acquire a signal from a transmitting communicator and to detect a valid starting flag and frame header. If any such frame header is received, the communicator is aware that a hub is present, otherwise no communication would be taking place. Upon successfully receiving any frame and upon examination of the contents of the header of the frame, the communicator detects from the frame type field whether the message is inbound or outbound to determine whether the source or the destination of the frame is acting as the hub.

If no hub is detected in the Listen RF state **250**, the communicator automatically will become the hub as the result of determining no other hub **64** exists, and will enter the Hub Active state **252**. In the Hub Active state **252**, the self-designated hub awaits transmissions from other communicators. If no transmissions are received for a predetermined period of time which is much longer than a communication cycle, the communicator acting as a hub enters an Idle state **254**, in which the communicator powers down its RF modem. The communicator will remain in the Idle state **254** for a predetermined period of time, after which it will resume the Listen RF state **250** to determine the presence of network communications. If the communicator is connected to a LAN segment, it may return to the Listen RF state **250** upon receipt of a LAN packet from the local LAN segment, if it is determined that the LAN packet is directed to a node on a remote LAN segment. Details of how the communicator may discern this is described in the above referenced invention which is incorporated herein.

On the other hand, if an active hub is detected while in the Listen RF state **250**, the communicator enters a Request Txop state **258**, in which a Txop request frame is sent to the active hub during the next Txop request interval **86**. The Txop request frame may elicit a number of responses from the hub. If the response is a Txop grant frame that allocates a Txop, the communicator enters the Remote Active state **260** and uses the allocated Txop. If the response is a Txop grant frame that denies the Txop allocation, the communicator returns to the Listen RF state **250**. If the response is a hub handoff request frame, indicating that the present hub has determined from the arbitration values contained in the Txop request frame, that the requesting communicator would make a better hub than the present communicator acting as the hub, the communicator responds by sending a hub handoff reply frame and then enters the Hub Active state **252**. Upon receipt of the hub handoff reply frame, the communicator acting as the hub ceases doing so and becomes a remote, using the last allocated Txop in the communication cycle.

The functionality of the communicators in each of the states **250**, **252**, **258** and **260** is discussed more specifically below in conjunction with FIGS. **16** to **19**.

In the Listen RF state **260**, the communicator performs the functions shown in the FIG. **16**, which are referenced there with separate reference numbers. The communicator scans all useable frequency channels listening for the presence of a hub by "listening" to each of the predetermined, useable frequencies, starting by selecting the next available frequency channel as shown at **251**. Having selected the available channel at **251**, the communicator activates its receiver for a duration equal to 110% of the predetermined maximum permitted time duration of a communication cycle as shown at **253**. By activating the receiver on each channel for 110% of the maximum time duration of a communication cycle, the communicator is certain to receive 100% of any communication cycle occurring, including the important information frames transmitted during the information interval **76** and the alternate information interval **82**.

If no RF activity is detected, as determined at **255**, the communicator then determines at **257** whether it has checked all available frequency channels. If the determination at **257** is that it has checked all available frequency channels, the communicator has made the determination that there are no other communicators active. Therefore, as the only active communicator, it becomes the hub, and enters the Hub Active state **252** (FIG. **15**). On the other hand, if the determination is made at **257** that there are as yet other unchecked frequency channels, the communicator selects the next available frequency channel at **251**, continuing in the Listen RF state.

Alternatively, if RF activity detected at **255**, the communicator further determines at **259** whether the detected RF activity represents a valid frame, or whether the detected RF activity represents an irrelevant RF

communication or interference. If the detected RF activity is a valid frame, the communicator enters a wait state at **261**, remaining with its receiver active on that same frequency channel until it receives an information frame transmitted during the information interval **76** or the alternate information interval **82**. Once an information frame is successfully received, the communicator will be able to determine the time of the next Request Txop interval **86** to request a Txop, and the communicator enters the Request Txop state **258**.

However, if the detected RF activity is determined at **259** not to be a valid frame, but before concluding that the RF activity is irrelevant, the communicator adjusts the calibration parameters of the receiver as shown at **263**. As discussed above, the communicator may adjust various calibration parameters to attempt to improve reception. The changed or improved reception allows another opportunity to determine whether the RF activity is a valid frame. Following the calibration adjustments at **263**, the determination is made at **265** if the RF activity presents a valid frame. If so, the communicator returns to the wait state at **261** to await reception of an information frame, at which time the communicator will transition to the Request Txop state **258**. If the determination made at **265** is that, even after adjusting the calibration parameters, the RF activity detected does not present a valid frame, the communicator makes a determination at **257** whether there are additional available channels to be checked. If there are additional channels to be checked, the communicator selects the next channel at **251**. If all available channels have been checked, as determined at **257**, the communicator transitions to the Hub Active state **252**.

In the Request Txop state **258**, the communicator performs the functions shown in the FIG. **17**, which are referenced there with separate reference numbers. The communicator enters the Request Txop state **258** after detecting the presence of a hub. From the information frame received during the Listen RF state **250**, the communicator determines the anticipated arrival time of the next Request Txop interval at **267**, at which time the communicator transmits a Txop request frame to the hub at **269**. The communicator then awaits a reply to its Txop Request frame from the hub, leaving its receiver active to receive the next communication cycle as shown at **271**. The communicator then makes a determination at **273** whether and what type of reply it has received from the hub in the next communication cycle.

If the determination is made at **273** that the communicator has received no reply from the hub, the communicator waits a random number of communication cycles as shown at **275**, and then determines at **267** the anticipated arrival time of the next Txop request interval **86**. The communicator waits a random number of cycles because its Txop request may have been interfered with by another Txop request from another communicator. Because it is possible that the hub did not properly receive the interfering Txop request frames and thus replied to none of them, waiting for a random number of communication cycles to send another Txop request reduces the chances of continued possible interference from another Txop request frame.

If the determination is made at **273** a Txop grant frame was received in response to the Txop request frame, a further determination is made at **277** as to whether the Txop number in the body of the Txop grant frame is zero or non-zero. A zero Txop in to the Txop grant frame indicates that the hub has denied a Txop to the communicator. A Txop denial will cause the communicator to transition to the Lister RF state **250**. On the other hand, if the Txop has been allocated, the communicator transitions to the Remote Active state **260**.

Alternatively, if the determination is made at **273** that a hub handoff frame has been received, the hub has decided that the requesting communicator is a better choice for the Group hub than the current hub. This occurs from an implicit hub arbitration process conducted at the active hub when each Txop request frame is received.

The arbitration criteria are stored in the ROM **92** or RAM **94** of each communicator and constitute a part of the MAC protocol of the present invention. The hub arbitration criteria are described in descending order of importance. First, the hub will consider whether either one of it and the new requester are powered by continuous AC power or whether each is battery powered. Because the hub's RF modem is continuously active for transmitting and receiving, it is highly desirable to have a communicator powered by continuous power. Second, if the first criterion is not dispositive because either both or neither of the communicators are continuously powered, the hub will consider whether one of these communicators has been preselected to act as a hub. Preselection may occur if, for example, it is known that a particular communicator is more centrally located or tends to encounter less interference than other communicators **60**, or if one communicator tends to remain stationary while other communicators are more frequently moved, etc. If one of the communicators has been preselected as a hub, that communicator will be selected as the hub. If this criterion is not dispositive because neither or both of the communicators has been predesignated as a hub, the third criterion will be employed. The third criterion involves whether there is a node on the local LAN segment attached to each communicator which is designated as a LAN server. Assuming that a communicator attached to a server will be involved in more LAN traffic and that the data transfer will be more efficient if it is accepted from a directly connected server, the communicator directly connected to the LAN server will be given priority as a hub. The fourth criterion gives priority to the communicator which is directly attached to the LAN segment having the greater number of active nodes. It is again assumed that the communicator attached to the LAN segment having the most active nodes will be involved in more LAN traffic than others, hence it will be designated as the hub. Finally, if all the functionally-based criteria fail to singularly designate the hub, that communicator having the lower OUI will become the hub.

It should be noted that more than two communicators could be involved in a hub arbitration, and the same criteria would be established to determine which of the plurality of communicators will be designated as the hub. The active hub either confirms its own selection and sends Txop grant frames to all those communicators sending Txop request frames, or designates the superior hub candidate by responding to the Txop request frame with a hub handoff request frame. Upon receipt of the hub handoff request frame the communicator in Request Txop state **258** utilizes the data in the body field of the hub handoff request frame, responds to the (outgoing) hub with a hub handoff reply frame at **279**, and enters the Hub Active state **252**. In this case the previous hub becomes the user of the last Txop (typi-

cally 15) of the communication cycle, as it enters the Remote Active state **260**.

In the Hub Active state **252**, the communicator performs the functions shown in the FIG. **18**, which are referenced there with separate reference numbers. The hub first allocates Txops based on Txop request frames received from the previous communication cycle as shown at **262**. Then, based upon the length and number of pending broadcast and directed frames and requested Txops, the communicator determines at **264** a coarse duration of the communication cycle, and the communicator then adjusts this duration at **266** with a randomly-selected fine duration adjustment.

Once the duration of the communication cycle has been established at **264** and **266**, the communicator assembles the information frame and transmits it to all of the remotes as shown at **268**. The hub determines at **270** if broadcast frames are pending and, if so, transmits the pending broadcast frames to all remotes as shown at **272**. After pending broadcast frames are sent or if the determination is made at **270** that there are no broadcast frames pending, the communicator determines at **274** if there are any pending directed frames. If there are, the directed frames are transmitted to the remotes as shown at **276**. After the directed frames are sent at **276** or if the determination is made at **274** that there are no directed frames to be sent, the communicator retransmits at **278** the information frame as the alternate information frame to all remotes. Next, if the determination made at **280** indicates that Txops have been allocated, the communicator receives the pending incoming frames from the remotes as shown at **282**. After receiving all the pending incoming frames, or if it is determined at **280** that there are no Txop allocations, the hub communicator then allows a predetermined interval of time to pass for remotes to transmit Txop request frames to the hub as shown at **284**, in the event that there may be newly active remotes which have not yet requested a Txop. After awaiting transmission of Txop request frames during the Txop request interval, the hub determines at **286** whether there is a need for a hub beacon interval in this communication cycle at **286**. If not, the hub returns to **262** to begin the next communication cycle. Otherwise, the hub sends a hub beacon frame at **288**, waits for possible hub beacon reply frames at **290**, and returns to **262** to begin the next communication cycle.

In the Remote Active state **260**, the communicator performs the functions shown in the FIG. **19** which are referenced there with separate reference numbers. The communicator activates its RF modem to receive the information frame from the hub as shown at **290**. The remote, based upon the information contained in the information frame, then makes a determination at **292** whether broadcast frames are pending and, if broadcast frames are pending, the remote receives the broadcast frames and queues them for transfer to the local LAN segment as shown at **294**. After the broadcast frames have been received at **294** or if the determination at **292** indicates that there are no broadcast frames pending, the communicator, based on the information contained in the information frame, makes the determination at **296** whether any directed frames are pending for transmission to it. If directed frames are pending, the communicator determines to activate its RF modem to receive the directed frames. The directed packet frames are received and the LAN packet portions thereof are queued for transfer to the local LAN segment as shown at **298**. If the determination is made at **296** that no directed frames are pending, the communicator can power off its RF modem, as shown at **300**, until it needs to be activated again.

After the directed frames are received from the hub as shown at **298** or the determination is made at **296** that there are no directed frames intended for the remote, the remote makes a determination at **302** whether its Txop is pending immediately. If the Txop is not immediately pending, the remote remains with its RF modem powered down until its Txop time arrives as shown at **304**. Once the Txop time arrives, the remote will determine whether it has any pending frames to send to the hub as shown at **306**. If inbound frames are pending, the remote activates its RF modem and transmits the pending frames to the hub as shown at **308**. On the other hand, if is determined at **306** that there are no pending frames, the remote sends a control frame to preserve its allocated Txop for use in later communication cycles as shown at **310**. Whether the remote transmits pending inbound data packet frames or a control frame to reserve its place, the remote will notify the hub in the BWAR field **184** and BWF field **186** of the header **162** of the number and size of pending frames it requests to send during the next communication cycle. The absence of such a frame, or a frame with a value of zero in the BWAR field yields a minimum length Txop for the next communication cycle.

Once the pending inbound frames are sent or the control frame is sent, the remote powers down its RF modem as shown at **312** and then returns to **290** to await the information frame at the start of the next communication cycle.

The previous description demonstrates the significant aspects of the MAC protocol of the present invention in providing efficient communication between communicators without the need for a wired communication medium and to accommodate communicators on a basis which permits them to join the Group on a non-specified basis, among other things. In addition, the protocol of the present invention offers significant advantages and improvements for use with battery powered communicators in allowing substantial power conservation, thereby extending the use time period for such communicators to a time period comparable to the use time period of the of a battery powered portable computer, thereby facilitating the use of such battery powered portable computers for information and resource sharing purposes though the single logical network available from the protocol of the present invention. Many other advantages and improvements will be apparent after comprehending the significant aspects of the present invention.

A presently preferred implementation of the MAC protocol of the present invention and many of its improvements have been described with a degree of particularity. This description has been made by way of preferred example, but the scope of the invention should not necessarily be limited by this exemplary description. What should be understood, however, is that the scope of the present invention is defined by following claims.

The invention claimed is:

1. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and

a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each communication cycle having intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting cycle establishing information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the hub transmitting a frame containing the cycle establishing information which establishes both an outbound portion of the communication cycle when the hub transmits frames to the remotes and an inbound portion of the communication cycle when the remotes transmit frames to the hub, the frame containing the cycle establishing information also establishing the predetermined intervals during the outbound and inbound portions of the communication cycle when each remote is allowed to transmit and receive;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the cycle establishing information transmitted from the hub; and

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the cycle establishing information transmitted from the hub.

2. A communicator as defined in claim 1 wherein the predetermined functions further comprise:

the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub; and

the hub transmitting transmission opportunity allocation information in the frame containing the cycle establishing information transmitted by the hub.

3. A communicator as defined in claim 2 wherein the predetermined functions further comprise:

the hub transmitting the frame containing the cycle establishing information to the remotes to establish a transmission opportunity request interval during the communication cycle when the remotes may transmit transmission opportunity request frames to the hub to request transmission opportunity allocations; and

the remotes transmitting transmission opportunity request frames to the hub during the transmission opportunity request intervals.

4. A communicator as defined in claim 3 wherein the predetermined functions further comprise:

the hub allocating a transmission opportunity to the remote within a predetermined number of subsequent communication cycles after the transmission opportunity request frame is received by the hub; and

the hub transmitting transmission opportunity allocation information during the communication cycle after the hub has received the transmission opportunity request.

5. A communicator as defined in claim 2 wherein the predetermined functions further comprise:

the hub allocating a predetermined amount of time for each transmission opportunity, the predetermined amount of time of the transmission opportunity being for a remote to transmit frames to the hub; and

the hub transmitting the frame containing the cycle establishing information which contains the transmission opportunity allocation information during the communication cycle.

6. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub;

the hub transmitting transmission opportunity allocation information in a frame transmitted by the hub; and

the hub allocating a number of transmission opportunities during at least one communication cycle which is at least one less in number than the number of remotes in the Group.

7. A communicator as defined in claim 6 wherein the predetermined functions further comprise:

the hub changing the transmission opportunity allocations in a subsequent communication cycle compared to a previous communication cycle by allocating a transmission opportunity to a remote which had previously not been allocated a transmission opportunity.

8. A communicator as defined in claim 7 wherein the predetermined functions further comprise:

the hub further revoking a previous transmission opportunity allocation of a remote to provide the transmission opportunity allocation to the remote which had previously not been allocated a transmission opportunity.

9. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub;

the hub transmitting transmission opportunity allocation information in a frame transmitted by the hub;

the hub transmitting information to the remotes to establish a transmission opportunity request interval during the communication cycle when the remotes may transmit transmission opportunity request frames to the hub to request transmission opportunity allocations;

the remotes transmitting transmission opportunity request frames to the hub during the transmission opportunity request intervals; and

the hub transmitting information in a frame which requires a remote having a previously allocated transmission opportunity to relinquish the transmission opportunity.

10. A communicator as defined in claim 9 wherein the predetermined functions further comprise:

the remote relinquishing its previously allocated transmission opportunity by transmitting a frame containing the acknowledgement during its allocated transmission opportunity request interval.

11. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub;

the hub transmitting transmission opportunity allocation information in a frame transmitted by the hub;

the hub monitoring the frames transmitted by each remote during its transmission opportunity; and

the hub revoking a previous transmission opportunity allocation of a remote which has not transmitted more than a predetermined number of frames during a previous number of communication cycles.

12. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub;

the hub transmitting transmission opportunity allocation information in a frame transmitted by the hub;

the hub allocating a predetermined amount of time for a transmission opportunity in each transmission opportunity, the predetermined amount of time of the transmission opportunity being for a remote to transmit frames to the hub;

the hub transmitting a frame containing the transmission opportunity allocation information during the communication cycle;

the hub adjusting the length of at least one transmission opportunity of at least one remote during at least one of a plurality of subsequent communication cycles; and

the hub transmitting a frame containing the information establishing the adjusted length of the transmission opportunity prior to the time of the adjusted transmission opportunity in a communication cycle.

13. A communicator as defined in claim **12** wherein the predetermined functions further comprise:

the hub monitoring the frames transmitted by each remote during its transmission opportunity; and

the hub further adjusting the length of the transmission opportunity relative to the number of frames transmitted by each remote during its transmission opportunity.

14. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub establishing the length of each communication cycle; and

the hub transmitting a frame containing information describing the length of the communication cycle prior to the end of the communication cycle whose length is established.

15. A communicator as defined in claim **14** wherein the predetermined functions further comprise:

the hub adjusting the length of a communication cycle relative to the length of a previous communication cycle.

16. A communicator as defined in claim **15** wherein the predetermined functions further comprise:

the hub continually adjusts the length of the communication cycles.

17. A communicator as defined in claim **15** wherein the predetermined functions further comprise:

the hub allocating transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub; and

the hub adjusting the length of a communication cycle relative to the number of transmission opportunities allocated.

18. A communicator as defined in claim **17** wherein the predetermined functions further comprise:

the hub allocating a predetermined amount of time for a transmission opportunity for a remote to transmit frames to the hub;

the hub monitoring the frames transmitted by each remote during its transmission opportunity; and

the hub further adjusting the length of a communication cycle relative to the number of frames transmitted by each remote during its transmission opportunity.

19. A communicator as defined in claim **17** wherein the predetermined functions further comprise:

the hub further adjusting the length of the communication cycle by a randomly generated factor.

20. A communicator as defined in claim **19** wherein the maximum length of communication cycle with the randomly generated factor is less than two times the maximum length of the communication cycle without the randomly generated factor.

21. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators Of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is ex-

pected to receive a frame from the hub, by using the information transmitted from the hub;

the hub transmitting two frames containing information to establish the plurality of predeterminable intervals during each communication cycle, the second frame containing the information to established the plurality of predeterminable intervals occurring before the intervals in which the remotes are allowed to transmit frames to the hub.

22. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, wherein the communicators are adapted to be connected to a resource to obtain data from and to supply data to the resource, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

a first remote transmitting a first frame containing data to the hub during an interval established in a first communication cycle, the first frame containing data obtained by the one remote from the resource connected to the one remote; and

the hub transmitting a second frame to a second remote during an interval established in a second subsequent communication cycle, the second frame containing the data contained in the first frame.

23. A communicator as defined in claim 22 wherein the physical distance between the first and second remotes is greater than the distance which either the first or second remote may reliably transmit frames.

24. A communicator as defined in claim 22 wherein the frames are transmitted by radio frequency signals and are received from radio frequency signals.

25. A communicator as defined in claim 24 wherein each remote further includes a plurality of antennas for receiving the radio signal, and the predetermined functions further comprise:

each remote selecting one among the plurality of antennas with which to receive the radio frequency signals during each communication cycle.

26. A communicator as defined in claim 25 wherein the predetermined functions further comprise:

each remote evaluating the strength of the received radio frequency signals with one antenna before selecting another antenna.

27. A communicator as defined in claim 26 wherein the predetermined functions further comprise:

the hub transmitting information to the remotes in a transmission unit which contains at least one frame, the transmission unit including a preamble; and

each remote evaluating the strength of the received radio frequency signals in the preamble before selecting another antenna prior to the end of the preamble.

28. A communicator as defined in claim 27 wherein the predetermined functions further comprise:

each remote further receiving a portion of the preamble with the other antenna after selecting the other antenna.

29. A communicator as defined in claim 24 wherein the Group is established by those communicators which transmit and receive the radio frequency signals on the same radio frequency channels.

30. A communicator as defined in claim 29 wherein the communicators transmit and receive the radio frequency signals using direct sequence spread spectrum modulation established by a predetermined spreading code, and the Group is established by those communicators which modulate and demodulate the radio frequency signals using the same predetermined spreading code.

31. A communicator as defined in claim 24 wherein the predetermined functions further comprise:

the hub transmitting the information to the remotes in a transmission unit which contains at least one frame, the transmission unit including a preamble; and

each remote synchronizing its receipt of signals transmitted from the hub during the communication cycle from the signal transmitted during the preamble.

32. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is

allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub transmitting information to the remotes to establish a first interval in the communication cycle during which a frame containing the information establishing the communication cycle and the plurality of predeterminable intervals is transmitted and a second interval during which the hub is allowed to transmit other frames to the remotes; and

each remote determines whether to power off its receiver during the second interval based on the information transmitted during the first interval.

33. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub transmitting a frame containing information to establish a first interval in the communication cycle during which the information establishing the communication cycle and the plurality of predeterminable intervals is transmitted, and a second interval during which the hub is allowed to transmit broadcast frames to the remotes, and a third interval in the communication cycle during which the hub is allowed to transmit directed frames to the remotes;

each remote powers its transmitter during the second interval; and

each remote determines whether to power off its receiver during the third interval based on the information conveyed during the first interval.

34. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined function comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub transmitting information to the remotes during a first communication cycle to establish the length of the first communication cycle and to establish the time for the beginning of the next subsequent second communication cycle; and

the remotes powering on their receivers at approximately the anticipated beginning of the second communication cycle after having powered their receivers off during the first communication cycle, by using the information transmitted from the hub during the first communication cycle.

35. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is ex-

pected to receive a frame from the hub, by using the information transmitted from the hub;

the hub transmitting information to the remotes to establish a predeterminable hub beacon interval during one of a predetermined plurality of sequential communication cycles; and

the hub transmitting a hub beacon frame during the hub beacon interval, the hub beacon frame containing information indicating that the hub is functioning as a hub for the Group and describing predetermined operational characteristics of the hub, the hub beacon frame being transmitted to another second hub of another second Group.

36. A communicator as defined in claim **35** wherein the predetermined functions further comprise:

the second hub receiving the hub beacon frame sent by the first aforesaid hub and in response thereto transmitting a hub beacon reply frame to the first hub during the hub beacon interval of the communication cycle of the first hub, the hub beacon reply frame containing information describing predetermined operational characteristics of the second hub; and

the first hub and the second hub responding to the information in the hub beacon reply frame and the hub beacon frame to adjust their respective transmissions of frames and to adjust the communication cycles established to avoid conflict in transmissions.

37. A communicator as defined in claim **36** wherein the predetermined functions further comprise:

the first and second hubs each adjusting their communication cycles so they do not overlap one another.

38. A communicator as defined in claim **37** wherein the frames are transmitted by radio frequency signals and are received from radio frequency signals, and the predetermined functions further comprise:

the first and second hubs transmitting the hub beacon and the hub beacon reply frames on the same predetermined radio frequency channel which is different than the radio frequency channels which the first and second hubs use for transmitting frames to and receiving frames from their remotes.

39. A communicator as defined in claim **37** wherein the frames are transmitted by radio frequency signals and are received from radio frequency signals, the communicators transmit and receive the radio frequency signals using direct sequence spread spectrum modulation established by a predetermined spreading code, and the predetermined functions further comprise:

the first and second hubs use different spreading codes for transmitting frames to and receiving frames from their remotes than the spreading codes used for transmitting the hub beacon and hub beacon reply frames.

40. A communicator as defined in claim **39** wherein the predetermined functions further comprise:

the first and second hubs transmit and receive the hub beacon frame and the hub beacon reply frame using a predetermined spreading code which is different that the spreading code used by each hub to transmit frames to and receive frames from the remotes of their respective Group.

41. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the hub assigning transmission opportunities to the remotes, each transmission opportunity being an interval for a remote to transmit frames to the hub;

the hub transmitting transmission opportunity allocation information in a frame transmitted by the hub;

the hub transmitting information to the remotes to establish a transmission opportunity request interval during the communication cycle when the remotes are allowed to transmit transmission opportunity request frames to the hub to request transmission opportunity allocations;

the remotes transmitting transmission opportunity request frames to the hub during the transmission opportunity request intervals to request transmission opportunities, the transmission opportunity request frames containing information describing predetermined operational characteristics of the remote transmitting the transmission opportunity request frame;

the hub responding to the information in the transmission opportunity request frame and determining if the remote is better suited to act as the hub based on a comparison of the operational characteristic information of the hub and the remote transmitting the transmission opportunity request frame;

the hub transmitting a hub handoff frame to the remote transmitting the transmission opportunity request frame if the hub has determined that the remote is better suited to act as the hub;

the remote responding to the hub handoff frame by transmitting a handoff acknowledgement frame and commencing to act as the hub after transmitting the handoff acknowledgment frame; and

the hub receiving the hub acknowledgement frame commencing to function as a remote after receiving the hub acknowledgement frame.

42. A communicator as defined in claim **41** wherein the communicators are adapted to be connected to a resource to obtain data from and to supply data to the resource, wherein the at least some of the communica-

tors are battery powered, and wherein the predetermined functions further comprise:

the hub determining if the remote is better suited to act as the hub by evaluating predetermined criteria describing operating characteristics obtained from the information of the transmission opportunity request frame and obtained from the hub, the operational characteristics including whether the hub or the remote is battery powered; and

the hub determining that the remote is better suited to act as the hub if the remote is not battery powered and the hub is battery powered.

43. A communicator as defined in claim **42** wherein the operating characteristics also include whether the hub or the remote is connected to a resource functioning as a server, and wherein the predetermined functions further comprise:

the hub determining that the remote is better suited to act as the hub if the remote is not connected to a resource functioning as a server and the hub is connected to a resource functioning as a server, after the hub has determined that both the hub and the remote are both connected to or both not connected to battery power.

44. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the communicators transmitting a transfer unit from one communicator to another which contains a plurality of frames;

the remotes transmitting a transfer unit having a header having at least one field containing information describing at least one frame of a previous transmission unit which was not successfully received by the hub; and

the hub responding to the field information describing the frame which was successfully received by transmitting in another subsequent transfer unit those remaining frames of the previous transfer unit which were not successfully received.

45. A communicator as defined in claim **44** wherein the frame has two fields containing information describing at least one frame of a previous transmission unit which was not successfully received, one field containing information describing the ending frame number of the last successfully received frame of the transfer unit, and the other field containing information describing a single frame in the plurality of frames in the transfer unit which was not successfully received.

46. A communicator for wirelessly transmitting frames to and receiving frames from a least one additional communicator in accordance with a predetermined medium access control protocol, the communicators which transmit and receive the frames constituting a Group, each communicator including a transmitter and a receiver for transmitting and receiving the frames respectively, the medium access control protocol controlling each communicator of the Group to effect predetermined functions comprising:

designating one of the communicators of the Group as a hub and the remaining the communicators of the Group as remotes;

the hub establishing repeating communication cycles, each of which has intervals during which the hub and the remotes transmit and receive frames;

the hub transmitting information to the remotes to establish the communication cycle and a plurality of predeterminable intervals during each communication cycle, the intervals being ones when the hub is allowed to transmit frames to the remotes, when the remotes are allowed to transmit frames to the hub, and when each remote is expected to receive a frame from the hub;

the remotes powering off their transmitters during times other than those intervals when the remote is allowed to transmit frames to the hub, by using the information transmitted from the hub;

the remotes powering off their receivers during times other than those intervals when the remote is expected to receive a frame from the hub, by using the information transmitted from the hub;

the remotes transmitting frames to the hub during the communication cycle which contain predetermined operational characteristic information of the remote transmitting the frame;

the hub responding to the operational characteristic information in the frame transmitted from each remote and determining if the remote is better suited to act as the hub based on a comparison of the operational characteristic information of the hub and the remote transmitting the frame;

the communicator functioning as the hub transferring the hub functionality to the remote having operational characteristics better suited to act as the hub; and

the remote receiving the hub functionality thereafter becoming the hub for the Group and the communicator previously functioning as the hub commencing to function as a remote.

47. A communicator as defined in claim **46** wherein the predetermined functions further comprise:

the hub transmitting information to the remotes to establish a transmission opportunity request interval during the communication cycle when the remotes are allowed to transmit transmission op-

portunity request frames to the hub to request transmission opportunity allocations;

the remotes transmitting transmission opportunity request frames to the hub during the transmission opportunity request intervals to request transmission opportunities, the transmission opportunity request frames containing information describing the predetermined operational characteristics of the remote transmitting the transmission opportunity request frame;

the hub transmitting a hub handoff frame to the remote transmitting the transmission opportunity request frame if the hub has determined that the remote is better suited to act as the hub;

the remote responding to the hub handoff frame by transmitting a handoff acknowledgement frame and commencing to act as the hub after transmitting the handoff acknowledgment frame; and

the hub receiving the hub acknowledgement frame commencing to function as a remote after receiving the hub acknowledgement frame.

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UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

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1. This brief complies with the type-volume limitation of Federal Rule of Appellate Procedure 32(a)(7)(b) because it contains 8, 703 words, excluding the parts of the brief exempted by Federal Rule of Appellate Procedure 32(a)(7)(B)(iii) and Federal Circuit Rule 32(b).

2. This brief complies with the typeface requirements of Federal Rule of Appellate Procedure 32(a)(5) and the type style requirements of Federal Rule of Appellate Procedure 32(a)(6) because it has been prepared using Microsoft Word in a proportionally spaced typeface using Microsoft Office 2010 in Times New Roman 14 point.

Dated: April 28, 2017

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